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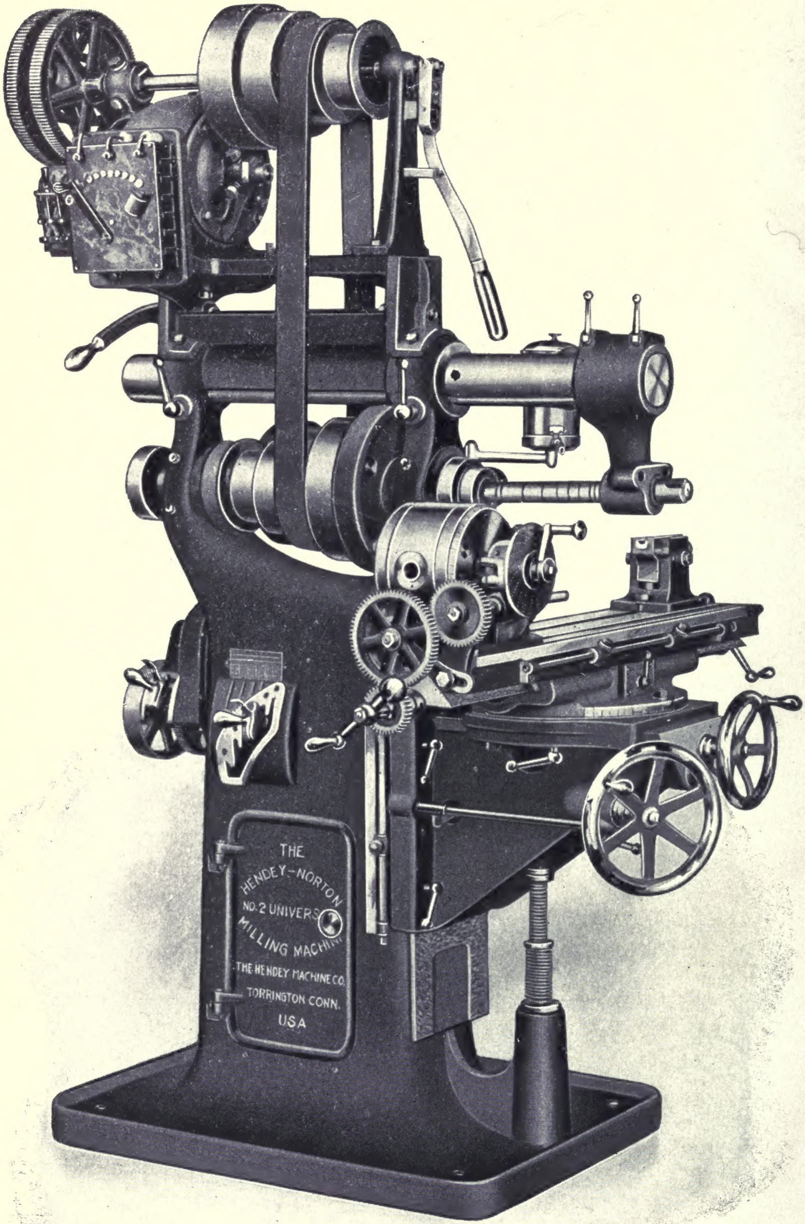

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost manufacturers and engineering firms, in making these volumes thoroughly representative of the best and latest practice in the design and construction of steam and gas engines, machine tools, and other classes of modern machinery; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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Foreword

THE rapid advances made in recent years in the field of Mechanical Engineering, as seen in the evolution of improved types of machinery, new mechanical processes and methods, and even new materials of workmanship, have created a distinct necessity for an authoritative work of general reference embodying the accumulated results of modern experience and the latest approved practice. The Cyclopedia of Mechanical Engineering is designed to fill this acknowledged need.

¶ The aim of the publishers has been to create a work which, while adequate to meet all demands of the technically trained expert, will appeal equally to the self-taught practical man, who, as a result of the unavoidable conditions of his environment, may be denied the advantages of training at a resident technical school. The Cyclopedia not only covers the fundamentals that underlie all mechanical engineering, but places the reader in direct contact with the experience of teachers fresh from practical work, thus putting him abreast of the latest progress and furnishing him that adjustment to advanced modern needs and conditions which is a necessity even to the technical graduate.

¶ The Cyclopedia of Mechanical Engineering is based upon the method which the American School of Correspondence has developed and successfully used for many years in teaching the principles and practice of engineering in its different branches. It is a compilation of representative Instruction Books of the

School, and forms a simple, practical, concise, and convenient reference work for the shop, the library, the school, and the home.

¶ The success which the American School of Correspondence has attained as a factor in the machinery of modern technical and scientific education, is in itself the best possible guarantee for the present work. Therefore, while these volumes are a marked innovation in technical literature—representing, as they do, the best ideas and methods of a large number of *different* authors, each an acknowledged authority in his work—they are by no means an experiment, but are in fact based on what has proved itself to be the most successful method yet devised for the education of the busy workingman. They have been prepared only after the most careful study of modern needs as developed under the conditions of actual practice in the Machine Shop, the Engine Room, the Drafting Room, the Factory, etc. The formulæ of the higher mathematics have been avoided as far as possible, and every care exercised to elucidate the text by abundant and appropriate illustrations.

¶ Numerous examples for practice are inserted at intervals; these, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a textbook with those of a reference work.

¶ Grateful acknowledgment is due the corps of editors and authors—engineers and designers of wide practical experience, and teachers of well-recognized ability—without whose co-operation this work would have been impossible.

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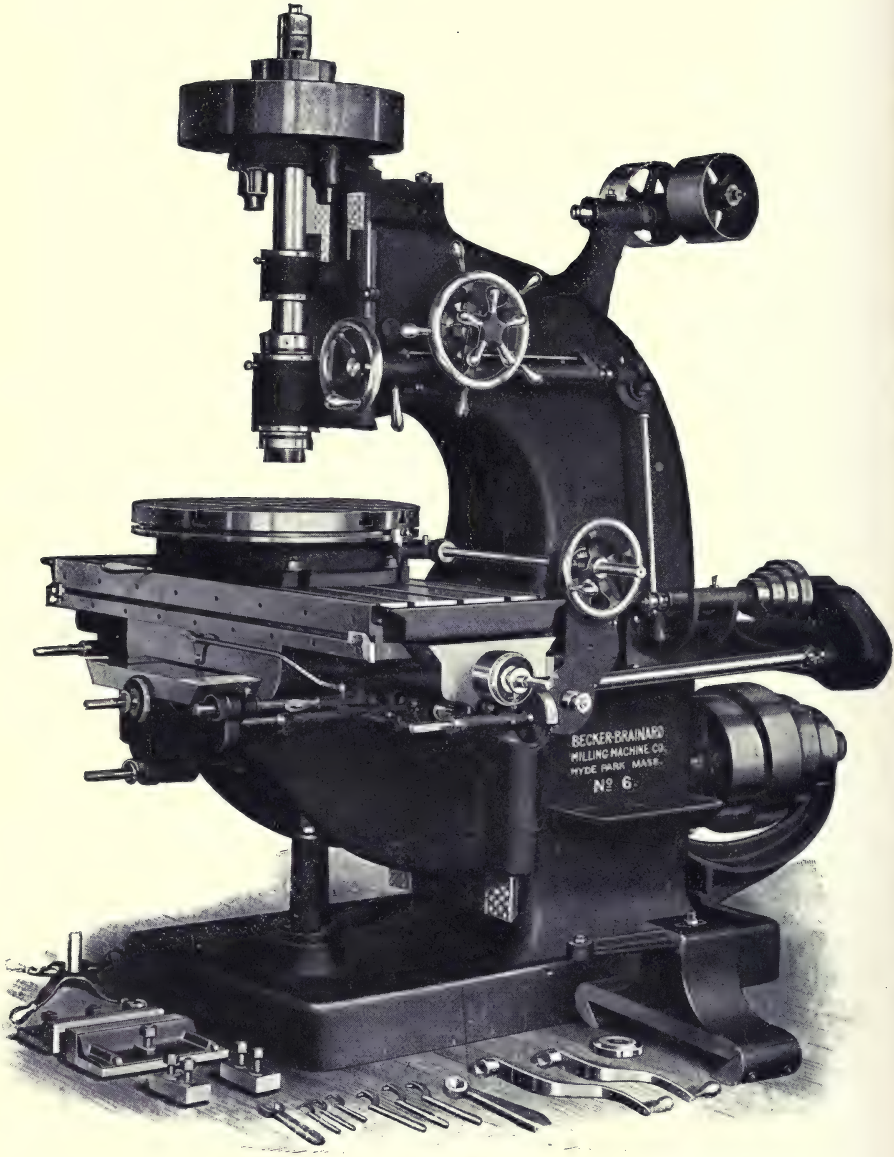

MILLING MACHINE.
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TOOL MAKING.

PART I.

As generally understood, a tool maker is a machinist who has a greater knowledge of the trade than is simply sufficient to enable him to make such machines or parts of machines, as may be the regular product of the shop in which he may be employed.

The business of the tool maker is to make the tools for producing the different parts of the machine, implement or apparatus, and relates not only to cutting tools, but to jigs and fixtures for holding the work while the various operations are being done, and making the necessary gauges to determine when the different parts are of the correct size and shape. Also the making of the models for the different fixtures and gauges. In some shops where there is work enough of the two latter described classes, the tool makers regularly employed on this work are termed gauge makers and model makers respectively. Yet in the average shop the models and gauges and such special machinery as may be required are made by the tool maker.

In order to acquire any degree of success, the tool maker must not only be able to work accurately and within reasonable time, but he must have a knowledge of drafting to enable him to read quickly and accurately any ordinary drawings. Unless he can read decimal fractions readily and accurately, he will experience much difficulty when working to measurements that require accuracy within one ten thousandth part of an inch. As most of the measuring instruments used by the tool maker read to one thousandth part of an inch, and some of them to the ten thousandth part of an inch, or even closer, it will be readily seen that in laying off measurements for gauges, models, drill-jigs and similar work, a thorough knowledge of Arithmetic is essential.

A tool maker should be familiar with the accurate reading of the micrometer and of the vernier as applied to the vernier caliper, vernier depth gauge and vernier height guage. He must bear in mind when using the vernier caliper for inside measurements that it is necessary to add the amount of space occupied by the caliper points A A Fig. 1 to the apparent reading on the vernier side.

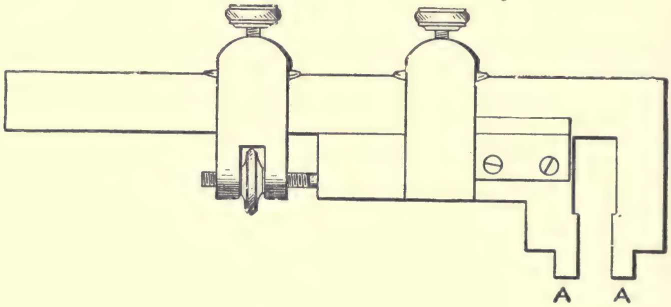


Fig. 1.

When measuring the distance between the centers of two holes as in Fig. 2, the vernier may be set so that the portions of the jaw marked A A Fig. 1 will exactly caliper the distance from B to B′ in Fig. 2. To the apparent reading of the vernier add the space occupied by the caliper points, and from this subtract one-half the diameter of each of the holes. It is necessary to caliper the size of *each hole*. Do not take anything for granted when accurate measurements are necessary. A reamer *should always* cut an exact size, but experience proves that it does not always do so. If the size of the hole is taken for granted, a variation of .002 inch means an error of .001 inch in a measurement.

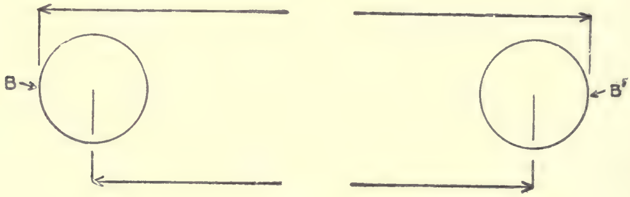


Fig. 2.

While extreme care should be exercised where accuracy is essential, there are parts of a tool where *approximate* measurements will do. If within $\frac{1}{16}$ inch is sufficiently accurate, it is folly to spend time to get a dimension within a limit of one ten thousandth part of an inch.

Approximate measurements are those made with the aid of calipers, dividers, surface guage, etc., set to an ordinary steel rule. Precise measurements are obtained by the aid of the various measuring instruments graduated to read to very small fractions of an inch. Also by the use of standard reference discs, and standard test bars, accurate within a limit of variation of $\frac{1}{50000}$ part of an inch. In using the micrometer, vernier or any of the measuring instruments supposed to give accurate readings, it is necessary to exercise great care in setting the tools. In setting the vernier it is well to use a powerful eye-glass in order that any error in setting may be so magnified as to be readily apparent.

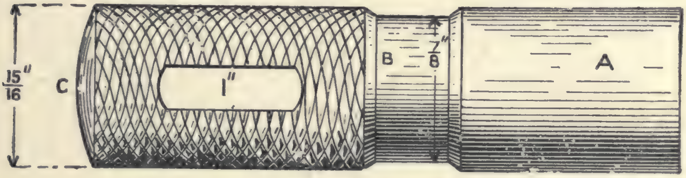


Fig. 3.

The difference between the two characters of measurements described — approximate and precise — may be readily seen in the plug gauge shown in Fig. 3. The gauge end A must be, when ground and lapped, *exactly* 1 inch in diameter, as shown by the stamped size on the handle C. The handle should be $\frac{15}{16}$ inch in diameter and knurled, and the neck $\frac{7}{8}$ inch. While the end marked A is necessarily a *precise* measurement, B and C are approximate, and an error of $\frac{1}{64}$ inch or more on either diameter would not interfere with the accuracy of the gauge. This does not mean that so great an amount of variation from given sizes should ever occur, but the illustration is given to show that the practical workman will never spend an unnecessary amount of time to produce accurate measurements when approximate measurements will do. On the other hand, all care possible should be taken when lapping the gauge end A to size.

Points to be Observed. Keep the working parts of any machine you may be running as clean as possible. Do not allow chips to collect on the shears (Vs) of your lathe. If these become roughed or worn, accurate turning cannot be done. Keep the machine thoroughly oiled, clean the oil holes out occasionally with a piece of wire, in order that the oil may get to the bearings.

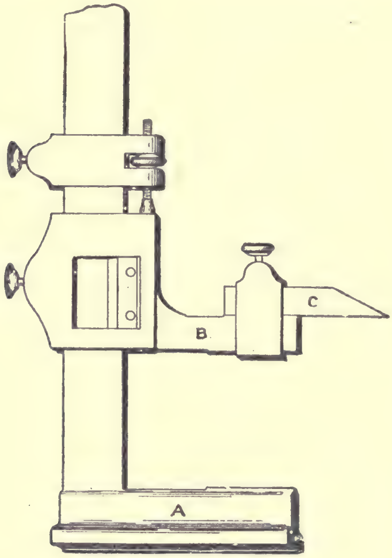


Fig. 4.

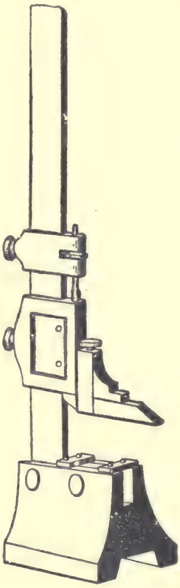


Fig. 5.

Keep the centers of your lathe in good condition, have them to gauge, and be sure the live center runs *true* before taking any finishing cuts. Try the center gauge on your countersink occasionally to see that it maintains its correct shape. Keep your center punch ground to a good point. It is advisable to grind the prick punch used in locating working points in some form of grinder having a chuck or collet to hold the punch while revolving it against the emery wheel; if the point is not perfectly round it will be impossible to indicate a piece of work perfectly on the faceplate of the lathe by means of the center indicator.

Special Tools. A vernier height gauge (Fig. 4) is a very handy tool for making drill jigs, templets and other tools requiring very accurate measurements, and for locating working points, holes or drill bushings. It is used for obtaining the height of projections from a plane surface, or the location of bushings in drill jigs, etc. The fixed jaw A is of sufficient thickness to allow the gauge to stand upright. An extension C attached to the movable jaw B can be used for scribing lines when laying off measurements. In the absence of a height gauge the regular vernier caliper may be made to answer the same purpose by making a base, which may be attached to the fixed jaw as shown in Fig. 5.

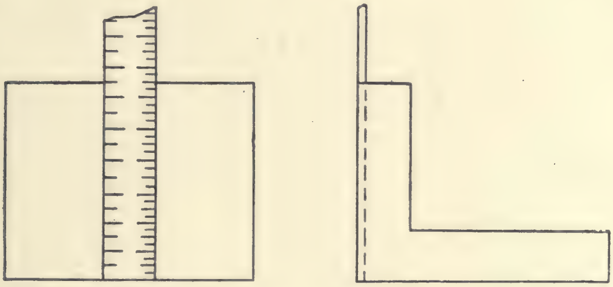


Fig. 6.

A small angle iron having a slot in the upright face to receive a scale for use in connection with a surface gauge when laying off measurements is shown in Fig. 6. The slot should be planed perfectly square with the base of the angle iron.

A pair of accurately machined V blocks is a necessary part of every tool maker's kit. If made of machinery or tool steel they will not need truing as often as if made of cast iron. After roughing out the V's, every surface should be planed square. They should be then clamped against the rail on the planer table by means of finger pieces, having previously trued the edge of the rail. The head of the planer should then be set to the proper angle, usually 45°, and one of the angles finished; the head may now be set over the opposite way and the other angle face planed. The tool used should be ground to give a smooth cut, as it is not advisable to do any finishing with a file or scraper.

A few small gauges of the most common angles will be found very convenient, as they can be used in places not accessible with the ordinary bevel protractor; the angles most commonly used are 60°, 65°, 70° and 80°. The form of gauge is shown in Fig. 7.

If the tool maker should be called on to make punch-press dies, one or more angle gauges, as shown in Fig. 8, will be found very useful. Many die makers use an adjustable square having a narrow blade which passes through the aperture in the die. The amount of clearance given is determined by the judgment of the workman; while this method does very well when practiced by an experienced man, it is rather uncertain when attempted by the novice. To get the proper clearance, the beginner should use the gauge shown in Fig. 8, called (improperly) a die maker's square.

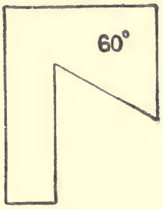


Fig. 7.

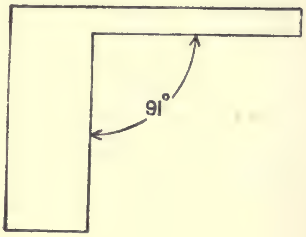


Fig. 8.

The angle depends on the nature of the stock, and the custom in the individual shop; but a set of three gauges, one 91°, one 91½°, and one 92° will meet the requirements, as the clearance is seldom less than 1° or more than 2°. The angle should be stamped on the wide part of the gauge, as shown in Fig. 7. To avoid springing out of shape the stamping should be done before the gauge is finish-filed at any point.

The tool maker should always have at hand a solution of blue vitriol for coloring the surface on which he is to draw lines. To make the solution, dissolve in a two-ounce bottle of water all the blue vitriol crystals the water will take up; to this add one-half teaspoonful of sulphuric acid. This produces a copper-colored surface when put on polished steel free from grease and dirt.

STEEL.

Tool steel is used for tools intended for cutting, pressing, or working metals or other hard materials to shape. In order to successfully work tool steel a knowledge of some of its peculiarities is necessary.

Carbon is the element in tool steel that makes it possible to harden it by heating to a red heat and plunging into a cooling bath. A bar of steel from the rolling mill or forge shop is decarbonized on its outer surface to a considerable depth; consequently this portion will not harden, or if it does the results will be far from satisfactory. For this reason if a tool is to be made having cutting teeth on its outer surface, it is necessary to select stock of somewhat greater diameter than the finish size, so that this decarbonized portion may be removed. About $\frac{1}{16}$ inch for sizes up to $\frac{1}{2}$ inch, $\frac{1}{8}$ inch for sizes up to $1\frac{1}{2}$ inches, $\frac{3}{16}$ inch for sizes up to 2 inches, and $\frac{1}{4}$ inch for sizes above 2 inches will usually be sufficient.

Tool steel may be procured in almost any form or quality. It is ordinarily furnished in round, octagonal, square or flat bars. Many tool makers prefer octagonal steel for tools which are to be circular in shape, but experience shows that steel of various shapes of the same make does not differ materially provided the quality and temper are the same.

Cutting tools should be made of high carbon steel if it is to be forged or hardened by skillful operators. If the steel is to be heated by an inexperienced man, it is not safe to select a steel having a high percentage of carbon.

For non-cutting tools, such as mandrels, it is well to select a low carbon steel (one per cent carbon or less), because with this steel there is not as great a tendency to spring when hardening.

Hammered steel is prized more highly than rolled steel by fine tool makers, but authorities do not agree on this point. It is generally conceded, however, that the best tools can be made from forgings if the heating and hammering have been correctly done. The steel should be heated uniformly throughout, and hammered carefully with heavy blows at first. Lighter blows should follow, and, when the piece passes from low red to black, great care is needed to prevent crushing the grain. Steel properly heated and hammered will have a close, fine grain.

Cutting from Bar. It is advisable when cutting a piece of stock from the bar to use a *cutting tool* of some description, such as a saw or cutting-off tool. It is decidedly poor practice to weaken the bar with a cold chisel and then break by a sudden blow or yank. This process so disarranges the particles of steel that they do not assume their proper relations with one another when hardened. If it is necessary to cut the steel with a chisel heat the bar to a *red heat*, as it may then be cut off without injury.

Centering. When centering, care should be taken that the center punch mark is exactly in the center of the piece on each end, so that an equal amount of the decarbonized material will be turned from all parts of the piece (see Fig. 9.) If centered as shown in Fig. 10 the decarbonized portion will be entirely removed at side marked B, and will not be on the side marked A, consequently when the piece is hardened the side marked B will be hard, while the opposite side A will be soft, or at least not as hard as B.

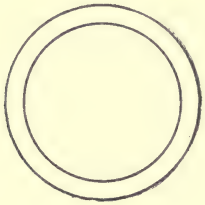


Fig. 9.

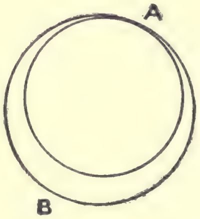


Fig. 10.

Straightening. A piece of tool steel that is to be hardened should *never* be straightened when cold. If it is bent too much to remove all the decarbonized steel when turning to size, it is best (generally speaking) to use a straighter piece of stock. But if the bent piece must be used, heat it to a red heat and straighten. A piece of steel straightened when cold is almost sure to spring when hardened.

ANNEALING.

In order that it may be soft enough to work easily, tool steel must be annealed. It can generally be bought in this condition cheaper than it can be annealed when needed in the factory. Annealing also removes the strains, or the tendency of the steel to crack and spring when hardened. Strains are caused by rolling and hammering in the steel mill or forge shop. In order to remove this tendency to spring, the piece of steel should be machined somewhere near to size, yet leaving sufficient stock to machine all over after the annealing. If it is a piece with a hole in it, such as a milling machine cutter blank, the hole should be drilled somewhat smaller than finish size ($\frac{1}{16}$ inch is the amount generally allowed) and the piece turned in a lathe to remove all the outer surface which contains the marks of the hammer or rolls. The piece is now ready for annealing. To anneal a piece of steel it should be heated to a uniform red heat and allowed to cool slowly. Steel may be annealed by any one of several methods.

Box Annealing. For this method it is necessary to have a furnace large enough to hold an iron box of sufficient size to take the piece to be annealed. To do this work cheaply, enough pieces should be annealed at a time to fill one or more boxes, according to the capacity of the furnace.

The material used in packing the box is wood charcoal, which should be ground or pounded until the particles are about the size of a pea. A layer of charcoal covering the bottom to a depth of one inch is first placed in the box, then a layer of steel. The different pieces should not come within $\frac{1}{2}$ inch of each other nor within 1 inch of the box at any point. The spaces between the pieces are filled with the charcoal, and they are covered to a depth of 1 inch. Another layer of steel may be put in if the box is of sufficient size. When within $1\frac{1}{2}$ inches of the top fill with charcoal, tamp down, put on the cover, and lute around the edges with fireclay, to prevent the direct heat of the fire entering the box.

Test Wires. There should be several $\frac{1}{4}$-inch holes drilled through the cover near the center, and through each of these a piece of $\frac{3}{16}$ inch wire should be placed. The wires should extend to the bottom of the box and project about 1 inch above the top of the cover in order to be readily grasped by the tongs. These wires are intended to be drawn from the box in order to determine when the contents are red hot. The box should be placed in the furnace. After the box has become thoroughly heated, one of the wires may be drawn out by means of a pair of long tongs. If no such tongs are available the legs of ordinary tongs may be lengthened by pieces of gas pipe. Note the time when the wire is red hot the entire length. If not red hot draw another in ten or fifteen minutes, and continue doing so until a wire is drawn that is red the entire length. The work should be timed from the time the box is heated through; this is shown by the wire.

The heat should be maintained a sufficient length of time to insure a uniform heat, which should not be allowed to go above a full red. The length of time the pieces remain in the fire depends somewhat on the size ; for steel 2 inches and under, one hour after the box is heated through will do ; larger pieces require a longer time. After running for the necessary length of time the heat should be shut off and the boxes allowed to cool slowly; the pieces should be left in the box until cold.

When there are no facilities for annealing by the method described, the piece may be heated to a uniform red and placed on a piece of board in an iron box, having one or two inches of ashes under the board. A second piece of board should be placed on the steel and the box filled with ashes. The pieces of wood will smoulder and keep the steel hot for a long time.

Another common method of annealing tool steel is to heat the piece to a red heat and bury it in ashes or lime. This is likely to give unsatisfactory results unless the ashes or lime are also heated. This can be accomplished by first heating a large piece of iron and burying in the contents of the annealing box. When the steel to be annealed is sufficiently heated the piece of iron may be removed and the piece to be annealed put in its place and thoroughly buried in order that it may take a long time in cooling; it should be allowed to remain in the ashes or lime until cold.

There is another method of annealing practiced in some shops, which answers in an emergency, but it is not to be recommended for general use. This is known as the *water anneal.* The piece of steel should be heated to a *low red*, making sure that the heat is uniform throughout. It should be removed from the fire and held in the air where no draft can strike it until no trace of red can be seen, even if the piece is held in a dark place ; it should then be plunged in water, and allowed to remain until cold. Better results may be obtained if plunged in soapy water or oil.

Long pieces which spring when annealed should not be straightened when cold, if they are to be hardened.

HARDENING.

Tool steel may be hardened by heating to a low red heat and plunging in some cooling medium, as water, brine or oil.

Heating. A piece of steel should never be heated any hotter than is necessary to give the desired result. The heat necessary varies with the make of the steel, the amount of carbon it contains, the size and shape of the piece, and the purpose for which it is to be used. Much depends on heating uniformly; a piece of steel should be given a *uniform heat throughout*, the edges and corners should be no hotter than the center, and the interior should be of the same temperature as the surface. If not, the piece is likely to crack in the cooling bath, on account of the uneven changes which take place in the molecular structure. While it is highly important that the steel is heated no hotter than is necessary, yet it is of *much more* importance that it be heated uniformly.

If the piece is heated in an ordinary forge, be sure that the air from the blast does not strike it. For a large piece build a large high fire; have it well heated through before putting in the steel. Use the blast only enough to keep a lively fire; have the steel well buried in the fire in order that the air may not strike it.

Cooling. When the piece is uniformly heated it should be plunged into a suitable bath to give it the proper hardness. It must be worked rapidly up and down, or around in the bath in order to get it away from the steam generated by the red hot steel coming in contact with the liquid, and also that it may constantly come in contact with the cooler parts of the bath. If the piece is long and slender it must be worked up and down; if it is short with teeth on the outer edge, as a milling machine cutter, it should be worked around rapidly in order that all the teeth may be cooled uniformly. If it is flat and has a hole through it whose inner walls must be hard, it should be swung back and forth in order that the bath may pass through the aperture and at the same time strike both faces.

If the tool is not to be hardened all over, and it is necessary to heat it higher than the point where the hardening is to stop, it may be dipped in the bath to a point a trifle higher than we wish it to harden, and then worked up and down a little. If this is not done there will be a line where the piece is expanded at one side and contracted on the other; it is likely to crack at this line, which is called a "water line."

Delicate articles, or those tools having long projections or teeth, should not be dipped in a bath of very cold water or brine; for such work a tepid bath gives better results.

Steel should always be hardened at a heat that leaves the grain *fine* when the piece is broken. This can be determined by hardening and breaking a small piece from the same bar from which the tool to be is made. A *coarse grain* denotes a heat higher than the steel should receive.

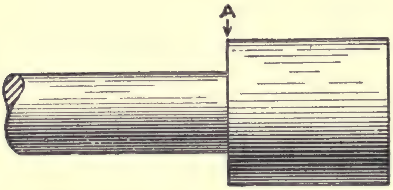
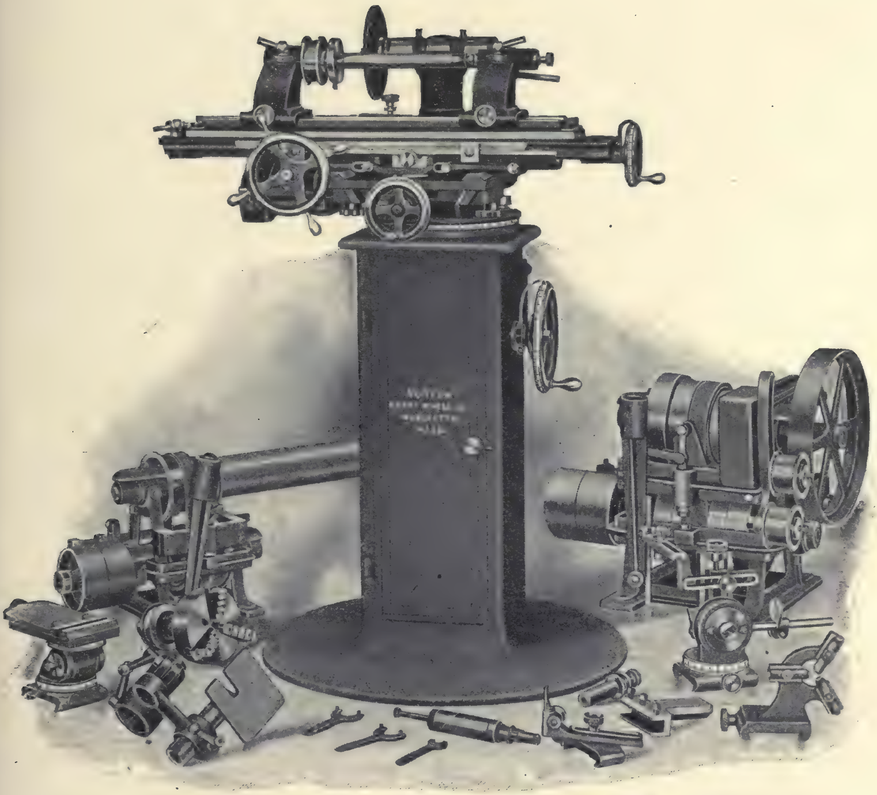


Fig. 11.

It will be found necessary when heating some kinds of steel to put the articles in an iron tube so that air cannot come in contact with them; this is especially true when hardening such tools as taps or formed mills whose outer surfaces cannot be ground, because the oxygen in the air acting on the carbon at the surface of the piece of steel *burns* it, leaving the surface decarbonized. Better results can be obtained with any tool if it is kept from the action of the air when heating for hardening.

When hardening a piece having a shoulder A, on the outside, as shown in Fig. 11, or inside, as shown in Fig. 12, hardening should not stop at the shoulder, as the unequal strains occasioned by the contraction of the hardened part at the shoulder are likely to cause it to crack at that point. The piece should not be hardened as high as the shoulder, but should it be necessary to do so, it is well to harden a little beyond.

Citric Acid Bath. An excellent bath for hardening small pieces may be made by dissolving one pound of citric acid crystals in one gallon of water. It should be kept tightly closed when not in use or it will evaporate. Small tools heated to a low



UNIVERSAL TOOL AND CUTTER GRINDER.
Norton Grinding Company.

red heat and dipped in this solution harden more uniformly than when immersed in clear water.

Pack Hardening gives excellent results with pieces that cannot be hardened by the methods ordinarily employed without risk of springing or cracking. The article is packed in an iron box with some carbonaceous material, and subjected to the action of heat to allow it to absorb enough carbon to harden in oil. While this method is not generally used, it is very valuable when hardening such pieces as milling machine cutters, blanking dies for punching presses, gauges, and taps where it is necessary that the diameter and pitch are not altered. The carbonaceous material is charred leather, which should be ground or pounded very fine (usually about one-half the size of a pea), and mixed with an equal quantity (volume) of wood charcoal whose granules are of about the same size. These should be thoroughly mixed. An iron box somewhat larger each way than the piece to be hardened should be selected. A layer of the packing material one inch deep should be placed in the bottom of the box and the piece laid on this; the box should then be filled with the packing material and tamped down. Fill the space between the cover and the box with fire clay, thus sealing it so that the gases in the box cannot escape and the direct heat of the fire cannot get into the box.

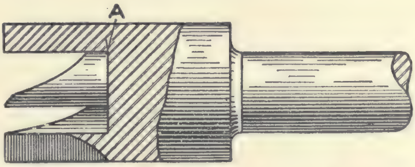


Fig. 12.

It is much more economical to pack a number of pieces at a time, as several may be hardened at the cost of one, and at a saving in packing material. The pieces should be wired with ordinary iron binding wire of a sufficient size to sustain the weight when the wire is red hot. One end of the wire should project over the outside edge of the box, and should be covered with the luting of fire clay. Several holes should be drilled near the center of the cover for test wires, as when annealing. The wires should extend to the bottom of the box. The box may now be heated sufficiently to charge the pieces with carbon. As steel does not commence to absorb carbon until it is red hot, the time is determined by means of the test wires as described under "Annealing." For ordinary tools $\frac{1}{2}$ inch diameter and under, run 1 hour to $1\frac{1}{2}$ hours after it is red hot; pieces from $\frac{1}{2}$ inch to 1 inch diameter, 2 to $2\frac{1}{2}$ hours; pieces from 2 to 3 inches diameter, $2\frac{1}{2}$ to 4 hours. The above must be varied according to the nature of the work.

After remaining in the furnace, the box should be taken out, the cover removed, and the piece taken out by means of the wire attached to it. It should then be immersed in a bath of *raw linseed oil.* The piece should be worked around in the bath until the red has disappeared; it may be then lowered to the bottom of the bath and allowed to remain until cold.

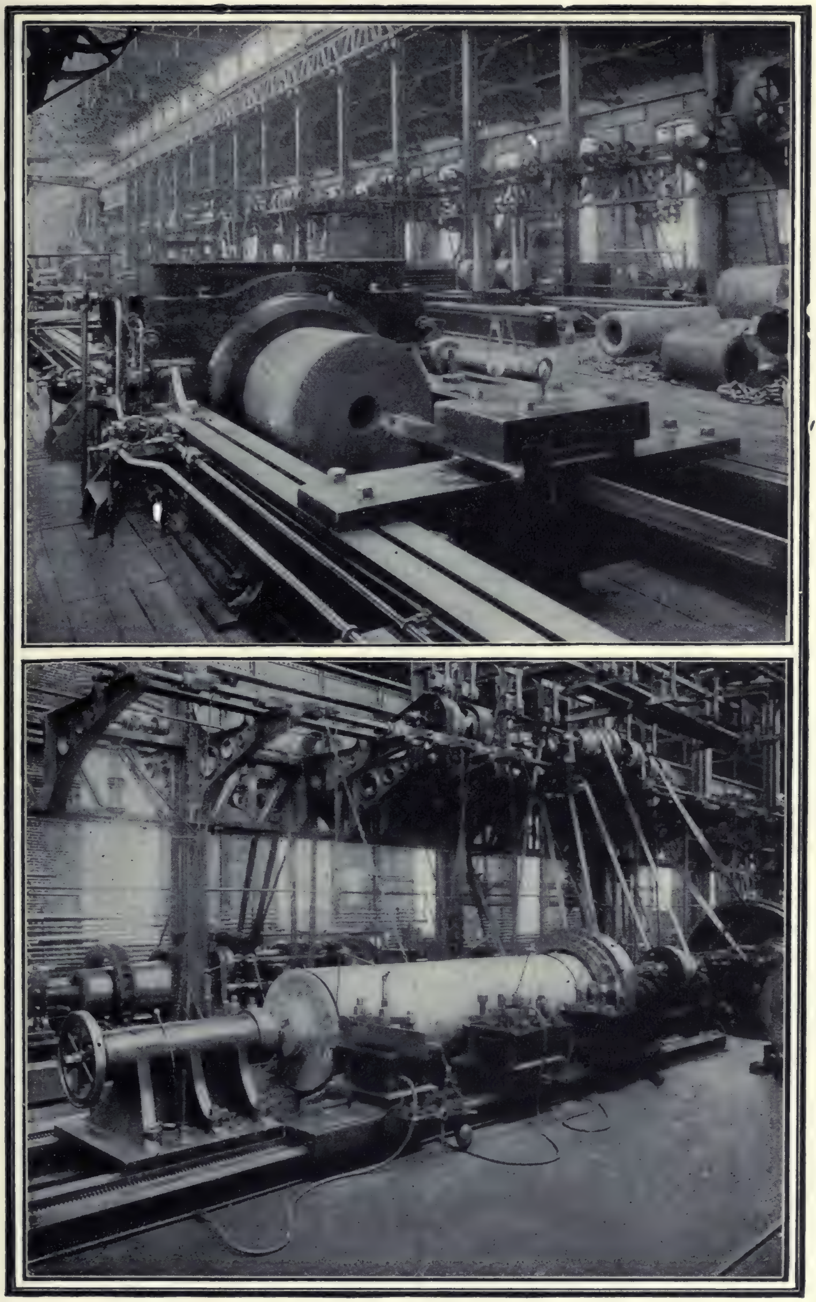
When a piece of steel one inch in diameter or larger is hardened, it should be reheated over the fire immediately on taking out of the bath, in order to avoid cracking, from the strains caused by molecular changes which take place after the outside surface is hardened and unable to yield to the internal strains. Reheating the surface to a temperature of about 212° will accomplish the desired result without materially softening the steel.

TEMPERING.

The hardening of a cutting tool makes it too brittle to stand up well when in use, and consequently it is necessary to soften it somewhat. This is known as "drawing the temper," and is accomplished by reheating to the proper temperature, which is ordinarily determined by the color of the surface of the tool, which must be brightened previous to this operation. As the piece of steel is heated, a light, delicate straw color will appear; then, in order, a deep straw, light brown, darker brown, light purple, dark purple, dark blue, pale blue, blue tinged with green, black. When black, the temper is gone. These colors furnish a guide to the condition of hardened steel.

The following list gives the color denoting the tempers generally used for tools:

Light straw	For lathe and planer tools, scrapers for brass, etc.
Deep straw	For milling cutters, reamers, large taps, etc.
Brown	For twist drills, drifts, flat drills for brass, etc.
Light purple	For augurs, screw slotting saws, etc.
Dark purple	For saws for wood, cold chisels, screwdrivers, etc.



CUTTING AND BORING A FLUID-COMPRESSED INGOT
BETHLEHEM STEEL WORKS

The following table gives the degree of heat corresponding to the different colors mentioned in the previous table.

Light straw	430 degrees F.
Deep straw	460 degrees F.
Brown	500 degrees F.
Light purple	530 degrees F.
Dark purple	550 degrees F.
Dark blue	570 degrees F.
Pale blue	610 degrees F.
Blue tinged with green	630 degrees F.

When work is tempered in large quantities the above method is expensive. Also it is not as reliable as when the articles are heated in a kettle of oil, using a thermometer for indicating the temperature. A piece of perforated sheet metal or wire cloth should be used to keep the articles two or three inches from the bottom of the kettle. A perforated sheet iron pail two inches smaller in diameter than the kettle, resting on a piece of iron, or a frame placed in the bottom will keep the pieces from the sides and bottom of the kettle.

The thermometer should be placed in the kettle outside the pail in order that the bulb may be at the same depth as the lower pieces.

Case Hardening. When an article of wrought iron or machinery steel is to have a hard surface it is treated while red hot with some material which forms a coating or case of steel, which hardens if dipped in water while red hot. Small articles such as nuts, screws, etc., may be case hardened by heating red hot and covering with a thin layer of powdered cyanide of potassium; when the cyanide of potassium melts, the article may be heated red hot again; it is then plunged into water. Care should be exercised when using this substance, as it is *extremely poisonous.*

The above method may be used for hardening a few pieces quickly, but it is not recommended for large quantities of work. When many pieces are to be case hardened at a time, the following method will be found less expensive and much more satisfactory:

Granulated raw bone and granulated charcoal should be mixed in equal quantities, and a layer of this mixture placed in an iron hardening-box to the depth of 1 or 1½ inches. A layer of articles is then placed on this; the pieces should not come within ½ inch of each other, nor within 1 inch of the walls of the box at any point; they should be covered with a layer of the mixture of bone and charcoal to the depth of ½ inch. Successive layers may be placed in the box until it is filled to within 1 inch of the top, when the cover may be put in place and the edges luted with fire clay. The test wires should be used as described for annealing. The heating should be timed from the time the contents of the box are red hot, which can be determined by the test wires. The length of time the work is allowed to run while red hot depends upon the desired depth of the hardened surface; generally carbon will penetrate wrought iron ⅛ inch in twenty-four hours, but as it is rarely necessary to harden deeper than $\frac{1}{32}$ inch, the work may be kept red hot three to four hours. With small pieces, the contents of the hardening-box may be dumped into a tank of running water; if the pieces are large, it is necessary to dip them one at a time in a bath, the same as for tool steel. For extreme toughness, the pieces, if small, may be dumped into a perforated sheet-metal pan and the *packing material sifted out*, after which they may be placed in a bath of oil; if not sifted out, the packing material will stay at the top of the oil and set fire to it. If the pieces are large, they may be dipped one at a time.

Spring Tempering. A piece of steel may be spring tempered by first hardening and then drawing the temper to a degree to which the piece, when bent, will return to its normal shape, when the pressure is removed. This may be accomplished by covering the surface with tallow or some animal oil, and then heating until the oil catches fire from the heat in the piece.

DRILLS.

The forms of drills commonly used in the machine shop are the flat drill, single-lip drill and twist drill.

Flat Drills, intended for use in the engine lathe for chucking, are usually forged to shape in the forge shop. After centering the end, which rests on the tail center of the lathe, the lips are ground to shape and the drill is ready for use. A drill of this description is shown in Fig. 13.

If it is necessary to have the drill cut nearly exact to size, it should be forged somewhat wider than finish size, and the edges turned in the lathe as in Fig. 14. The projection A must be left on the cutting end to provide a center for turning. If the drill is to be ground to size after hardening, the projection must be left on until the grinding has been done, but, ordinarily, this class of drill is not intended to cut exact enough to require grinding.

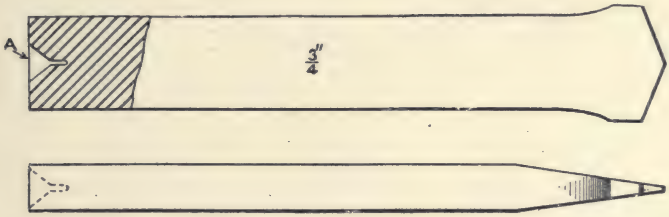


Fig. 13.

If the edges of the drill are not to be ground to size, they should be draw-filed a small amount to avoid binding. The filing should not come within $\frac{1}{64}$ inch of the edge, and should be only a small amount (.003 or .004 inch will be found sufficient); if given too much relief the drill will jump and chatter. The shank should be somewhat smaller ($\frac{1}{32}$ to $\frac{1}{16}$ inch) than the cutting end in order not to touch the sides of a hole drilled deep enough for the shank to enter. The center in the shank end should be large, to insure a good bearing on the tail center of the lathe, as shown at A, Fig. 13.

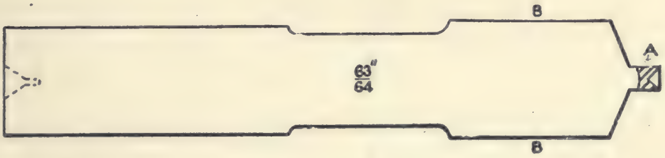


Fig. 14.

When hardening, the drill should be heated a *low red* to a point above the cutting end, preferably about one-half the length of the portion turned smaller than the ends. When dipped in the bath it should be plunged about one inch above the cutting end. To insure good results it should be worked up and down and around in the bath, which may be either water or brine. The temper should be drawn to a brown color.

When a flat drill is intended for use in a drill press, the shank is left round, in order that it may be held in a chuck or collet.

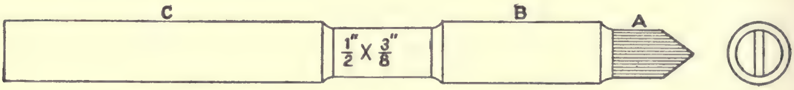


Fig. 15.

Transfer Drill. Another form of flat drill termed a transfer drill, is very useful when a small hole is to be transferred from a larger. The shank C, Fig. 15, may be made of any convenient size; the portion B is of the size of the larger hole, while A is of the size of the hole to be transferred, and is a short *flat* drill.

When making this drill, if a lathe is used having draw-in split chucks, the drill may be made from drill rod, which should be enough larger than finish size to allow B to be turned, to insure its running true with A; the cutting part A may be milled or filed to thickness. The cutting lips are then backed off, and the drill hardened. It should be hardened high enough so that A and B are hard, as the portion A does the cutting, while B, being a running fit in a hole, is likely to rough if it is soft.

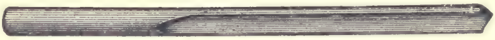


Fig. 16.

To harden it should be heated in a tube and dipped in water or brine, and worked up and down, to avoid soft spots caused by steam .keeping the water from the metal, as sometimes happens when a piece has different sizes close together. The cutting portion A should be drawn to a deep straw color; B should be left as hard as possible, to resist wear.

Straightway, or straight fluted drills, have the flutes cut parallel to a plane passing through the axis of the drill, as shown in Fig. 16. They are used in drilling brass, and in drilling iron and steel when the holes break into one another, as shown in Fig. 17.

The smaller sizes may be made of drill rod. After cutting to length, the blank may be put in a chuck in the lathe and the end pointed to the proper cutting angle. When milling the flute, the shank may be held in the chuck on the end of the spiral head spindle. The head should be set at an angle that makes the flute deeper at the cutting end of the drill than at the shank end; this causes an increase of thickness at the shank, thus making the drill stronger than if the flute were of uniform depth throughout. The milling cutter should be of a shape that will make the cutting face of the drill a straight line when the drill is ground to the proper cutting angle. The corner should be somewhat rounded. The general shape of the cutter is shown in Fig. 18.

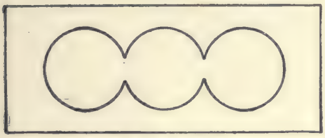


Fig. 17.

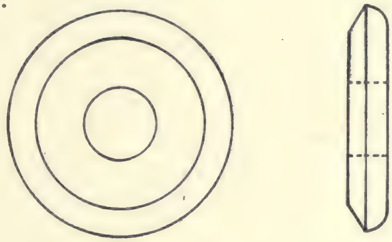


Fig. 18.

Single Lip Drill. For certain classes of work the single lip drill is very useful. Having but one cutting edge its action is similar to that of a boring tool used for inside turning in the engine lathe. The body of the drill being the size of the hole drilled insures its cutting a straight hole, even when used in drilling work partly cut away, or castings having blow-holes or similar imperfections. It does not cut as rapidly as the other forms, consequently is not used where a twist drill would do satisfactory work. Fig. 19 shows a form of single lip drill to be used with a bushing. The steel for this drill should be somewhat larger than finish size, in order that the decarbonized surface may be removed;

the cutting end A and the shank B should be turned .014 to .020 inch larger than finish diameter to allow for grinding after the drill is hardened. The portion C should be turned to finish size and stamped. In order that the drill may be ground to size after it is hardened it will be found necessary to face the end back, leaving the projection containing the center as shown at A in Fig. 20. The cutting end should be milled to exactly one-half the diameter of B. After milling, the face C should be draw-filed until it is flat and smooth. When hardening, the drill should be slowly heated to a low red, a trifle higher than the portion that is to be cutting size; it should be plunged in a bath of warm water or warm brine in order to avoid as far as possible any tendency to springing or cracking in the projection A. The tendency to crack is due to its peculiar shape and the difference in its size and that of the drill. After hardening it may be drawn to a straw color.

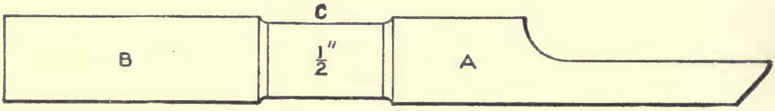


Fig. 19.

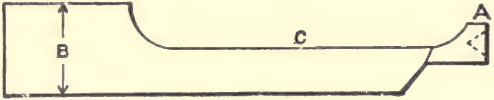


Fig. 20.

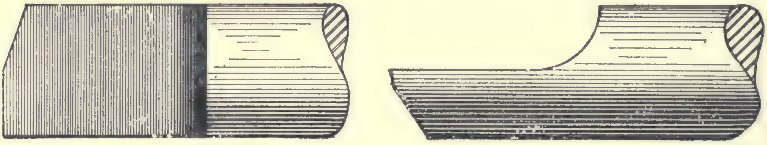


Fig. 21.

When grinding it is advisable to grind the shank first, in order that the grinding machine may be adjusted to grind straight;

after grinding the shank and cutting end to size, the projection A may be ground off, and the cutting end given the required shape, as shown in Fig. 21.

When a single-lip drill is to be used on iron and steel and not upon brass, it may be made to cut more freely by giving the cutting-face rake, as shown in Fig. 22. This may be done by milling the portion A to the proper dimensions, which should be one-half the diameter of the blank. The end and sides of the drill may now be coated with the blue vitriol solution and the desired shape marked out, after which it may be placed in the milling machine vise at the proper angle, and the required amount of rake given by means of small end cutters. After giving the necessary end clearance as shown in the two views of Fig. 22, the drill is ready for hardening.

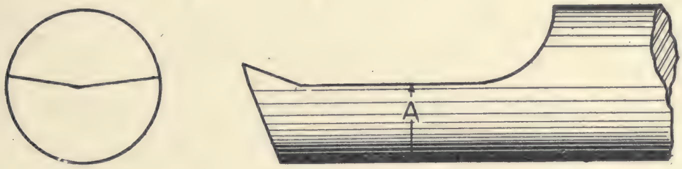


Fig. 22.

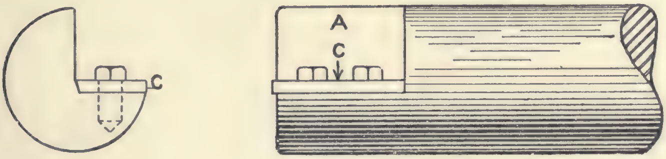


Fig. 23.

In order to adjust a drill of this kind to compensate for wear, it may be made as shown in Fig. 23, in which one-quarter of the circumference is cut away at A and a blade or cutter fastened in position; the top face of the cutter should be radial. To compensate for wear, pieces of paper or thin sheet metal may be inserted under the blade.

When cutting away the portion A, three holes may be drilled, as shown in Fig. 24. If square corners are desired, care should be taken that the holes are located so that they will machine out when milling to the proper dimensions. After drilling, the body of the drill may be placed in a vise in the shaper, and by the use of a cutting-off tool (parting tool) the portion may be removed, but as it would be impossible to cut to finish dimensions it will be necessary to finish with small end milling cutters, holding the tool in the chuck on the spindle of the spiral head. After machining one surface, the spindle may be revolved one quarter turn and the other surface machined; this insures square corners, and two surfaces at right angles to each other. The surface on which the cutter is to rest should be cut below the line of center, so that the top edge of cutter may be radial; that is, it should be cut the thickness of the cutter below a line passing through the center. See Fig. 23.

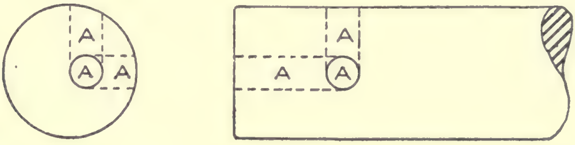


Fig. 24.

The cutter should be made of tool steel; two holes should be drilled for the fastening screws. After fastening the cutter in position it may be turned to the proper diameter by running the body of the tool in the steady rest of the lathe. Care should be used not to cut into the body or holder. After turning to size and facing the end square, the cutter may be removed from the holder, and necessary clearance given the end by filing; the outer edge may be draw-filed in order to smooth it, and a slight clearance given to prevent binding; this may be done by removing a trifle more stock at the bottom than at the top edge. To harden it should be heated to a low red heat and dipped in luke-warm water; the temper may be drawn to a straw color.

Twist Drills. In general it is cheaper and more satisfactory to buy twist drills than to attempt their manufacture in the ordinary machine shop; but at times a *special* size or length of drill is needed, or, for some cause, it is necessary to make them.

For the smaller sizes it is best to use commercial drill rod. For drills larger than $\frac{1}{2}$ inch diameter select larger stock and turn it to the desired size. If true holes of the size of the drill are required, it is advisable in the case of drills larger than $\frac{1}{2}$ inch diameter, to turn them .010 to .015 inch larger than finish size, and grind to the required size after hardening. A projection (Fig. 25) containing the center should be left on the cutting end of the drill until after the grinding has been accomplished. After cutting the flutes and grinding the drill, the projection may be ground off and the cutting lips ground to the proper shape, as shown in Fig. 26.

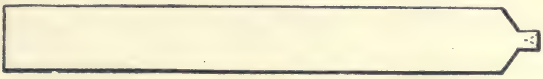


Fig. 25.

When making drills of the smaller sizes from drill rod, the blanks may be cut and pointed to the proper angle on the cutting end; this may be done in the lathe holding the blank in a chuck. The proper angle is 59° from one side of the blank. When milling the flutes of a twist drill on a universal milling machine, the shank of the drill, if straight, may be held in a chuck or collet of the right size, and if very long may be allowed to pass through the spiral head.

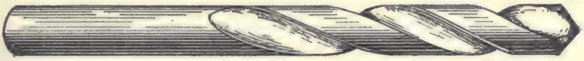


Fig. 26.

The following explanation and table are taken from Brown & Sharpe Co.'s book, entitled "Construction and Use of Milling Machines," and are intended for use with the cutters manufactured by them when cutting the flutes in twist drills.

The cutter is placed on the arbor directly over the center of the drill, and the bed is set at the angle of spiral, as given in the following table:

Diameter of Drill.	Thickness of Cutter.	Pitch in Inches.	Gear on Worm.	First Gear on Stud.	Second Gear on Stud.	Gear on Screw.	Angle of Spiral.
$\frac{1}{16}$	.06	.67	24	86	24	100	16° 20′
$\frac{1}{8}$	.08	1.12	24	86	40	100	19° 20′
$\frac{3}{16}$	.11	1.67	24	64	32	72	19° 25′
$\frac{1}{4}$	.15	1.94	32	64	28	72	21°
$\frac{5}{16}$	.19	2.92	24	64	56	72	20°
$\frac{3}{8}$	.23	3.24	40	48	28	72	21°
$\frac{7}{16}$	.27	3.89	56	48	24	72	20° 10′
$\frac{1}{2}$	.31	4.17	40	72	48	64	20° 30′
$\frac{9}{16}$	.35	4.86	40	64	56	72	20°
$\frac{5}{8}$	.39	5.33	48	40	32	72	20° 12′
$\frac{11}{16}$	.44	6.12	56	40	28	64	19° 30′
$\frac{3}{4}$	.50	6.48	56	48	40	72	20°
$\frac{13}{16}$	.56	7.29	56	48	40	64	19° 20′
$\frac{7}{8}$	.62	7.62	64	48	32	56	19° 50′
$\frac{15}{16}$	.70	8.33	48	32	40	72	19° 30′
1	.77	8.95	86	48	28	56	19° 20′

The depth of groove in a twist drill diminishes as it approaches the shank, in order to obtain increased strength at the place where the drill is otherwise generally broken. The variation in depth depends on the desired strength or the use of the drill. To obtain the necessary variation of depth, the spindle of the spiral head is elevated somewhat, depending on the length of the flute to be cut; when less than 2 inches in length the angle should be $\frac{1}{2}$ degree: 5 inches and over in length, 1 degree. Usually this will be found satisfactory, but for extremely long drills the elevation must exceed these amounts. The outer end of the drill must be supported, as shown in Fig. 27, and when small should be pressed down firmly until the cutter has passed over the end.

It is somewhat better to use left-handed cutters, so that the cut may begin at the shank end, in order to lessen the tendency of lifting the drill blank from the rest. When large drills are held by the centers the head should be depressed in order to decrease the depth of the groove as it approaches the shank.

Another very important operation on the twist drill is that of "backing off" the rear of the lip, to give it the necessary clearance. In Fig. 28 the bed is turned to about $\frac{1}{2}$ degree, as for cutting a right-hand spiral, but as the angle depends on several conditions it will be necessary to determine what the effect will be under different circumstances. A study of Fig. 28 will be sufficient for this by assuming the effect of different angles, mills, and the pitches of spirals. The object of placing the bed at an angle is to cause the mill E to cut into the lip at C and have it just touch the surface at C. The line R being parallel with the face of the mill, the angular deviation of the bed is clearly shown at A in comparison with the side of the drill.

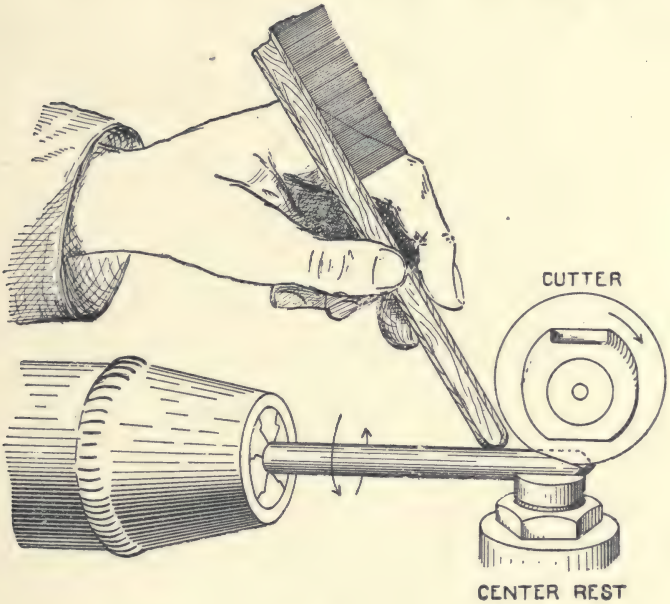


Fig. 27.

While the drill has a positive traversing and relative movement, the edge of the mill at C must always touch the lip a given distance from the front edge, this being the vanishing point; the other surface forming the real diameter of the drill is beyond the reach of the cutter, and is left to guide and steady it while in use.

The point C as shown in the enlarged view, Fig. 28, shows where the cutting commences and its increase until it reached a maximum depth at C, where it may be increased or diminished according to the angle employed in the operation; the line of cutter action being represented by I I.

Before backing off, the surface of the smaller drills in particular should be oxidized by heating until it assumes some distinct color to clearly show the action of the mill on the lip of the drill, for, when satisfactory, a uniform streak of oxidized surface, from the front edge of the lip back, is left untouched by the mill, as represented in the cut at E.

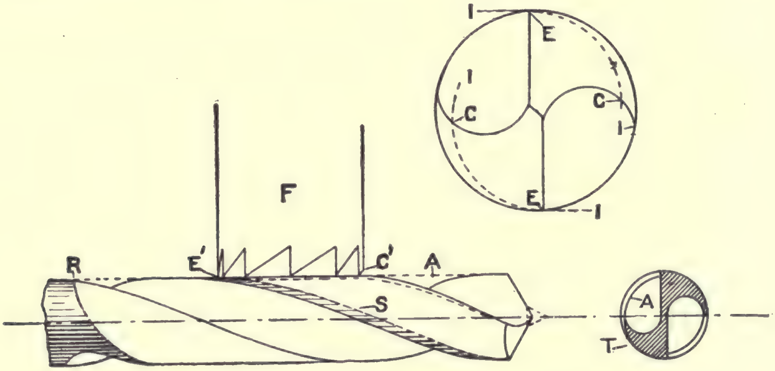


Fig. 28.

If the drills are to be ground without being centered, pointed projections (60°) may be made on the ends as shown in Fig. 28; these projections may be run in female centers in the grinding machine. If tapered back about .003 inch in 6 inches it will be found that the clearance thus obtained will cause them to run much better.

Hardening Twist Drills. Twist drills are hardened by special processes which, generally speaking, are not understood outside the shop where the drills are made. Very good results, however, may be obtained if the drills are heated somewhat and dipped into a solution of the following:

Pulverized charred leather	1 pound
Fine Family Flour	1½ pounds
Fine Table Salt	2 pounds

The charred leather should be ground or pounded until fine enough to pass through a number 45 sieve. The three ingredients are thoroughly mixed while in the dry state, and water is then added *slowly*, to prevent lumps, until the mixture formed has the consistency of ordinary varnish.

After the drill has been dipped in the mixture it should be laid in a warm place to dry; when thoroughly dried the drill may be heated in a tube, or preferably in a crucible of red-hot lead until it is a low red, when it may be plunged in a bath of luke-warm water, or brine; small drills may be dipped in a bath of oil. The drill must not be put in red-hot lead until the coating is thoroughly dried, as the moisture may cause minute particles of lead to fly in all directions, endangering the eyes of the operator. After hardening, the temper may be drawn to a full straw color. If several drills are hardened at a time the temper may be drawn by placing them in a kettle of oil over a fire gauging the amount of heat by a thermometer, as explained under heading of "Drawing Temper."

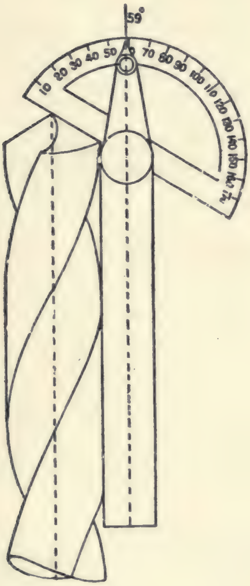


Fig. 29.

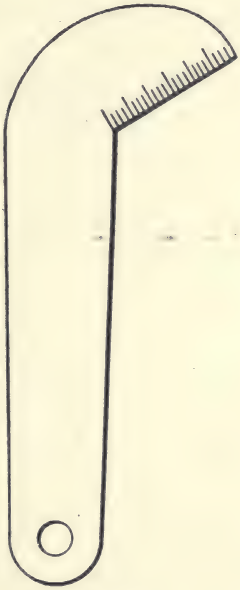


Fig. 30.

Grinding Twist Drills. The cutting edges must make a proper and uniform angle with the longitudinal axis of the drill; they must be equal in length, and the lips of the drill sufficiently backed off for clearance, otherwise they will not cut easily, or they will make a hole *larger* than the size of the drill.

Drills properly made have their cutting edges straight when ground to a *proper* angle, which is 59 degrees, as in Fig. 29. Grinding to an angle less than 59 degrees leaves the lip hooking, which is likely to produce a crooked and irregular hole.

A very satisfactory form of angle gauge for this work is shown in Fig. 30; the graduations on the upper part of gauge show when the lips are ground to an equal length, which is essential in order that the drill shall cut the proper size. As the operator becomes experienced he can gauge the angle and length of lips very accurately by the eye, but until he has the necessary experience it is advisable to use some form of gauge.

REAMERS.

A reamer is a tool that makes a smooth, accurate hole; however, in many cases reamers are used to enlarge a cored hole, or a hole already drilled, without particular reference to the exact size or condition of the hole. Reamers may be classified according to shape as follows: straight reamers, taper reamers, and formed reamers. Reamers are made solid, adjustable, and with inserted blades.

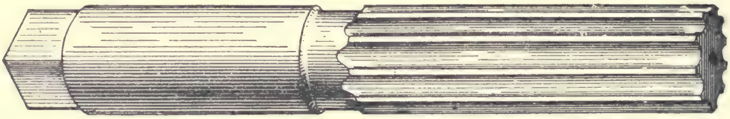


Fig. 31.

Solid reamers (Fig. 31) are so called because the cutting teeth and head are made from one piece; they have no means of adjustment as to size. The cutting teeth of inserted blade reamers are made from separate pieces of steel, and inserted in the head as shown in Fig. 32. The adjustable reamer may be made with inserted teeth, or with cutting teeth solid with the head; but in either case having some means of adjusting the size.

STRAIGHT REAMERS.

Under this heading the following kinds of reamers are to be found: fluted hand reamers, fluted chucking reamers, rose reamers, single lip reamers, and three and four lipped roughing reamers.

The Fluted Hand Reamer is made straight on the cutting lips, with the exception of a short distance at the end (A Fig. 33) which is slightly tapered in order that the reamer may enter the hole. In making such reamers, use steel from $\frac{3}{32}$ inch to $\frac{1}{8}$ inch above finish size. Turn a chip off the outside surface to a depth of $\frac{1}{32}$ inch and anneal, then turn A and B Fig. 33 to sizes .010 to .015 inch larger than finish size; turn C to finish size, mill the end D square for a wrench. The reamer is now ready to have the flutes cut.

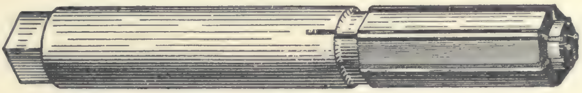


Fig. 32.

Number of Cuttting Edges. Fluted reamers designed to remove but a small amount of stock, and intended to cut holes to an accurate size are rarely given less than six flutes.

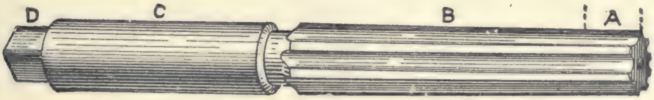


Fig. 33.

The following table gives the number of cutting edges that give satisfaction for solid reamers whose flutes are milled by cutters made to give the proper shape.

TABLE OF CUTTING EDGES FOR REAMERS.

$\frac{1}{8}''$ to $\frac{7}{16}''$	diameter	6 teeth
$\frac{1}{2}''$ to $\frac{11}{16}''$	"	6 to 8 "
$\frac{3}{4}''$ to $1''$	"	8 "
$1\frac{1}{16}''$ to $1\frac{1}{2}''$	"	10 "
$1\frac{9}{16}''$ to $2\frac{1}{8}''$	"	12 "
$2\frac{1}{4}''$ to $3''$	"	14 "

Formerly it was considered necessary to have an odd number of cutting edges; but an even number if unevenly spaced will be as satisfactory. The chief objections to an odd number are the difficulty experienced in calipering unless a ring gauge is used, and the great cost of grinding.

Fig. 34 shows a form of cutter that makes a strong reamer tooth and allows the chips to be removed very readily. These cut the tooth ahead of the center, and should be given a negative rake of about 5°. In general, a reamer will cut more smoothly if the tooth has a slight negative rake, as it then takes a scraping cut.

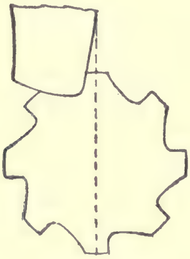


Fig. 34.

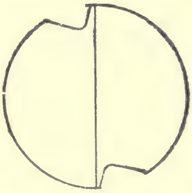


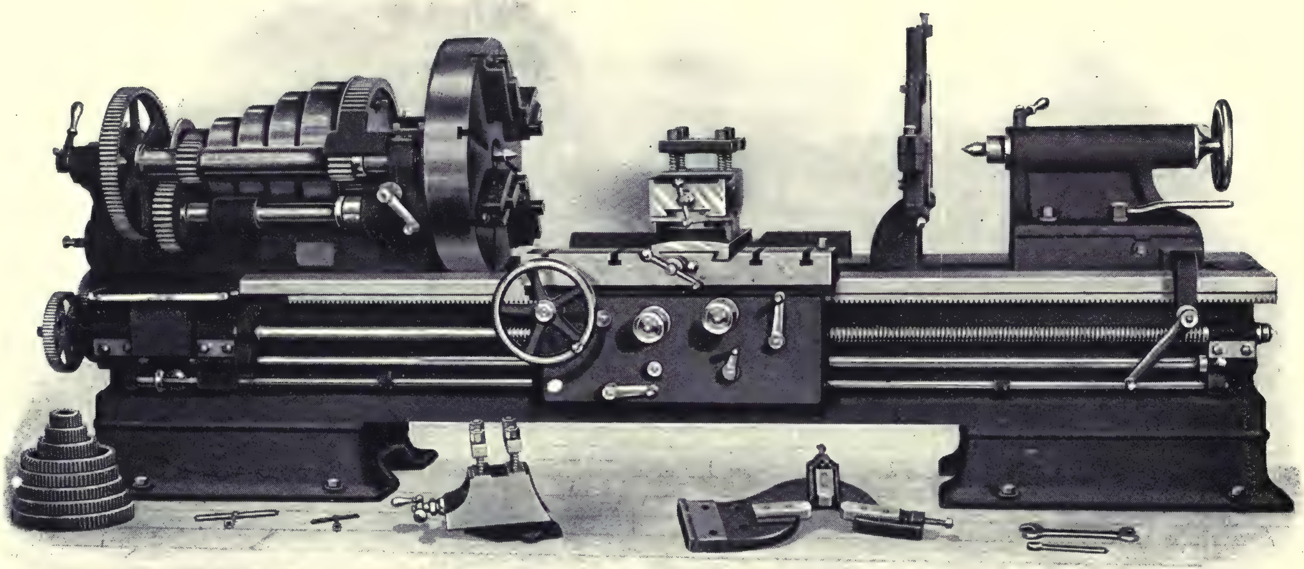
Fig. 35.

With this form of flute, the depth of cut must be so gauged that the land will be about $\frac{1}{5}$ the average distance from one cutting edge to the other; if cut deeper, the teeth will be weak and have a tendency to spring, if not as deep, there will not be room for the removal of the chips. The following table shows the number of cutter (shown in Fig. 34) for any size of reamer.

NUMBERS OF CUTTERS FOR REAMERS.

No. 1	Cutter	cuts	reamers	from	$\frac{1}{8}''$ to $\frac{3}{16}''$	diameter.
No. 2	"	"	"	"	$\frac{1}{4}''$ to $\frac{5}{16}''$	"
No. 3	"	"	"	"	$\frac{3}{8}''$ to $\frac{7}{16}''$	"
No. 4	"	"	"	"	$\frac{1}{2}''$ to $\frac{11}{16}''$	"
No. 5	"	"	"	"	$\frac{3}{4}''$ to $1''$	"
No. 6	"	"	"	"	$1\frac{1}{16}''$ to $1\frac{1}{2}''$	"
No. 7	"	"	"	"	$1\frac{9}{16}''$ to $2\frac{1}{8}''$	"
No. 8	"	"	"	"	$2\frac{1}{4}''$ to $3''$	"

In order that reamers may be calipered readily when grinding — if the teeth have been unevenly spaced — the teeth must be diametrically opposite each other; the unevenness in spacing must



32′′ x 12′ TRIPLE-GEARED LATHE.
Hamilton Machine Tool Company

be between adjoining teeth. This is done by cutting one tooth, then turning the spiral head of the milling machine half-way round (by giving the index pin twenty revolutions) and then cutting the opposite tooth. When cutting the flutes in pairs, the number of times the cutter must be set for depth of cut is reduced one half. Fig. 35 shows an end view of reamer having the first pair of flutes cut as described.

The irregularity of spacing is obtained by moving the index pin a different number of holes for each adjoining pair of flutes.

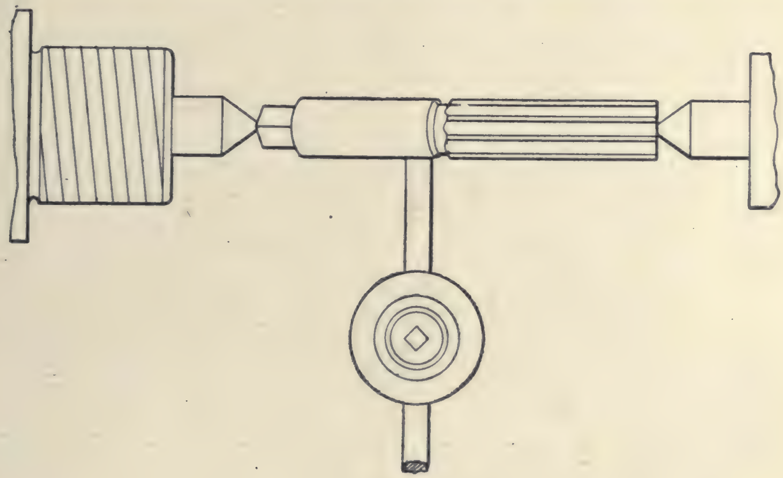


Fig. 36.

This irregularity need not be great; a variation of a few degrees, 2°, 3° or 4° from an angle corresponding to regular spacing is generally considered good practice.

Hardening Reamers. In order that a reamer may not spring when hardened, great care should be exercised in heating. If a muffler furnace is at hand, a uniform heat may be obtained. If heated in a blacksmith's forge the reamer should be placed in a tube to prevent the fire from coming in contact with the steel; it should be turned frequently to insure uniform results. While cooling, the reamer should be held vertically to avoid springing, and should be worked up and down in the bath.

If the reamer is one inch diameter, or larger, it should be removed from the hardening bath when it stops *singing*, and plunged into oil, and allowed to remain until cold. The temper may be drawn to a light straw color.

If reamers are hardened by the "Pack Hardening" process, the danger of springing is greatly reduced.

Straightening Reamers. If a reamer springs while hardening and tempering, it may be straightened by the following method: Place the reamer between the centers of the lathe; fasten a tool, or piece of iron or steel having a square end in the tool post (Fig. 36), placing the square end against the reamer at the point of greatest curvature. The surface of the reamer should be covered with a thin coating of sperm, or lard oil. With a spirit lamp, a plumber's hand torch, or a Bunsen burner, heat the reamer evenly until the oil commences to smoke; pressure may now be applied by means of the cross-feed screw, slowly forcing the reamer over until it is bent a trifle the other way. It should be cooled evenly while in this position. After it is cool the pressure may be relieved and the reamer tested for truth. If it does not run true the operation may be repeated. This method of straightening is equally effective when applied to other classes of work.

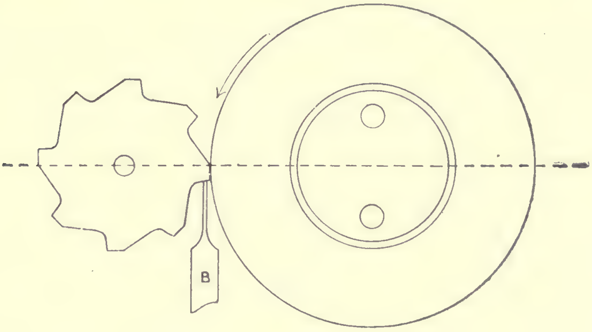


Fig. 37.

The straightening should be done before drawing the temper. When drawing the temper the heat should be applied evenly or the piece will spring from uneven heating.

Before *grinding a reamer* be sure that the centers of the grinding machine are in good shape, then clean the centers of the reamer. The reamer should first be ground to run true. It may be ground to within .001 or .002 inch of finish size; large reamers having the greater amount. In backing off a reamer tooth for clearance use an emery wheel of as large diameter as possible without striking the cutting edge of the next tooth. The correct clearance is given by a finger which can be adjusted. Fig. 37 shows an end view of reamer being ground for clearance together with the finger and emery wheel. The emery wheel should run in the direction indicated by the arrow, in order that the pressure of the wheel will tend to force the reamer tooth down on the finger B. To give clearance, the finger is adjusted so that the cutting edge is below the line of centers as shown. The lower the finger the greater the amount of clearance. Unless a free cutting wheel, free from glaze is used the temper will be drawn, thus rendering the reamer worthless. To avoid softening the teeth, the stock must be removed by a succession of light cuts going way around the reamer each time the adjustment is changed.

A reamer will soon lose its size if the clearance is ground to the edge of the teeth; consequently it is best to grind to within from .01 to .015 inch of the edge, according to the size of the reamer. The reamer is then brought to an edge and to the desired size by oilstoning. To do satisfactory work the stone should be free cutting. Select a stone of medium grade for removing the stock, and use a "fine" stone for finishing the cutting edge. An oilstone should *not* be used dry; keep the face free from glaze. If there are deep depressions or marks in the stone, face it off on a wet grinding machine.

Fluted Chucking Reamers. The same general instructions given for making fluted-hand reamers, can be applied to this form; except that the shank may be finished to size before the reamer is hardened, unless the shank is to fit a collet or be held in a chuck.

The regular jobbing reamer used in the lathe is shown in Fig. 38; the form for the chucking lathe or drill press, where the shank is held in a collet or chuck is shown Fig. 39. When making this style of reamer, B may be left .010 to .015 inch above size to allow for grinding. The portion C may be finished to size and the dimension of the cutting part of the reamer stamped on it as shown; if the reamer is made for special work and is to be used on no other, the name of the piece, or operation it is intended for should also be stamped.

On account of the uncertainty of a reamer cutting exactly to size when used in a lathe, chucking reamers are frequently made somewhat under size. Standard *hand* reamers are used for finishing. The amount of stock left for the hand reamer varies: some tool makers consider .005 inch the proper amount for all reamers up to 3 inches in diameter; while others think that for 1 inch or less diameter .004 inch is right; and for sizes from $1\frac{1}{16}$ inches to 2 inches, .007 inch should be allowed. For reamers larger than 2-inch diameter an allowance of .010 inch should be made. The exact amount necessary for finishing with hand reamers depends on the nature of the work and the stock operated on. Fluted chucking reamers are made with either straight or spiral flutes.

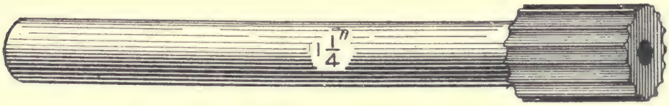


Fig. 39.

When a reamer is used in a screw machine or turret lathe, on work where accuracy and straightness of hole is essential, it should be held in some form of special holder, which allows it to properly locate itself as to alignment. Such holders will be described later under the heading " Reamer Holders."

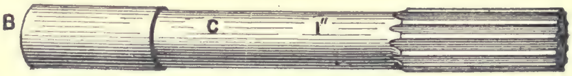


Fig. 39.

Rose Reamers. This form of reamer has its cutting edges only on the end as shown in Fig. 40, the grooves being cut the entire length of body to reduce the amount of frictional-bearing surface and to furnish a channel to conduct the lubricant to the cutting lips. In case there are blow holes or other imperfections in the material being operated on, this reamer will cut a more nearly parallel hole than the fluted chucking reamer.

Fig. 40 shows the ordinary form of rose chucking reamer. The shank B is turned to finish size; in case it is to fit a holder it is left slightly larger and turned or ground to size after hardening. The body A is turned .015 to .020 inch above finish size, the flutes cut, the size stamped as shown, and the reamer hardened a little above the body. It is customary when grinding a rose reamer to make it a trifle smaller on the end of body next to the shank; a taper of $\frac{1}{4000}$ inch in the length of the cutting part gives good results.

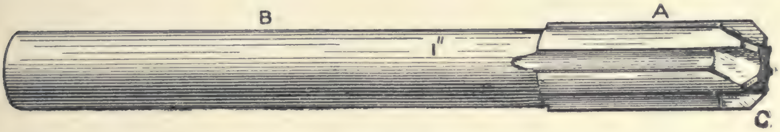


Fig. 40.

Small rose reamers can be made of drill rod, which runs very true to size, if ordered by the decimal equivalent rather than by the drill gauge number, or in terms of common fractions. For instance, if drill rod is wanted of a size corresponding to No. 1 Browne & Sharpe drill gauge, the wire will come much more accurate if ordered .228 inch diameter rather than by the gauge.

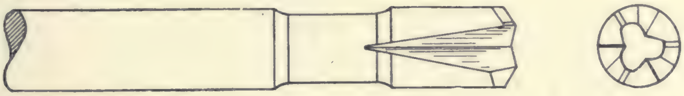


Fig 41.

The wire may be sawed to length, put in lathe chuck, and cornered for the cutting lips. When making small reamers that are not to be ground to size after hardening, it is advisable to neck them down back of the cutting edge, as shown in Fig. 41. The drill rod often swells or expands at a point where the hardening ends, and by necking down and hardening into the necking this difficulty is overcome.

Small rose reamers may be given three cutting edges. The flutes may be filed with a three-square or a round-edge file. If a three-square file is used, a groove of the form shown in Fig. 41 may be made. This has a tendency to push the chips ahead when cutting, while a groove filed with a round-edge file, if it be of a spiral form, will draw the chips back into the flute, provided it is a right-hand helix, as shown in Fig. 42.

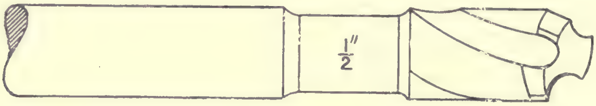


Fig. 43.

Rose reamers intended for reaming holes of exact size must be ground to correct dimensions after hardening, but small reamers intended for reaming holes where *exactness* of size is not essential may be made to size before hardening, and the cutting edges backed off with a file for clearance. If reamers are ground on the circumference for size, the lips or cutting edges should be given clearance by grinding. After grinding, the corners of the cutting edges next to the body of the reamer, as shown at C, Fig. 40, should be rounded by oilstoning.

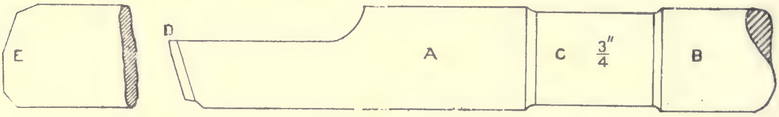


Fig. 43.

A Single Lip Reamer is very useful for reaming a *straight* hole. When the nature of the hole or the condition of the stock would cause the ordinary forms to *run*, the single lip reamer will cut a straight hole if started right. Having but one cutting lip, its action is similar to a boring tool used for internal turning in the lathe, and as a large proportion of the body of the reamer acts as a guide, it must cut a straight hole. Fig. 43 shows two views of this form of reamer.

Steel for this reamer should be sufficiently large to allow the decarbonized surface to be entirely removed. After a roughing chip has been taken,— leaving the piece about $\frac{1}{16}$ inch above finish size,— the stock should be annealed, after which the portions A and B should be turned to a size that allows for grinding. C may be finished to dimensions given, and the size of the reamer stamped as shown.

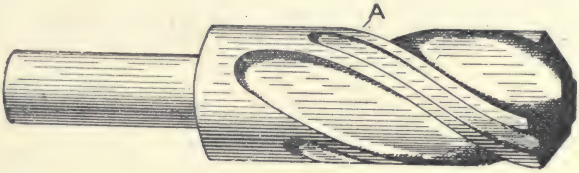


Fig. 44.

The reamer is now ready for milling. This should be done with the reamer in the centers in the milling machine, using a shank mill or a small milling cutter on an arbor. The depth of the cut should be about one-third the diameter of the reamer; for large reamers it may be somewhat deeper. After milling, the face may be smoothed with a fine file, and the end and cutting lip backed off for clearance, as shown in Fig. 43 at D and E.

When hardening, the end A should be heated to a low red and dipped in the bath about one-half an inch on the necked portion C. The temper may be drawn to a light straw. A and B are now ready for grinding. If the grinder has no provision for water to run on the work, care should be used not to heat the reamer, as it is likely to spring.

Three and Four Lipped Roughing Reamers are used to advantage in chucking machines for enlarging cored holes, or holes that have been drilled smaller than the required size. This is often done in making large holes in solid stock, as most manufacturers consider it more economical to use a smaller drill and a roughing reamer in order to bring them to proper size for the final reamer. Fig. 44 shows a reamer of this description.

The instructions already given for making the various reamers may be followed for this form, with the exception of cutting the grooves, which should be of a sufficient size to hold the chips. The small groove cut in the center of the lands is to feed oil to the cutting edges when cutting steel. When cast iron is the material to be operated on, the grooves are cut straight and the oil groove omitted. If a finish reamer is to be used in sizing the holes, it is customary to make the roughing reamer $\frac{1}{64}$ inch smaller than finish size. On account of the rough usage, great care should be exercised in hardening. While satisfactory results may be obtained by heating to a *low* red, plunging in a bath of brine, and drawing the temper to a light straw, the tools will do a great deal more if they are pack hardened by the process already described.

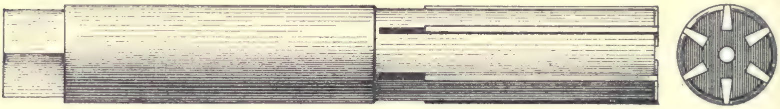


Fig. 45.

Inserted Blade Reamers. The particular advantage of solid reamers with inserted teeth is that when worn, new blades may be put in at a cost much less than that of a new solid reamer. Inserted blade reamers are usually made in such a manner that the size may be altered; in such cases they are termed expanding reamers. A simple form is shown in Fig. 45. The slots for the blades are milled somewhat deeper at the front end than at the end toward the shank; they are also somewhat wider at the bottom than at the top. The first is accomplished by depressing the spiral head a trifle, while the latter is done by first milling the slots with a cutter a little narrower than the top of the slot wanted, then turning the spiral head enough to produce the desired angle on one side of slot as shown at A in Fig. 46. The object in making

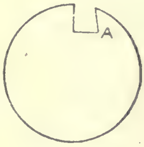


Fig. 46.

the slot deeper at the front end is that the blades, as they become dulled (and consequently cut small), may be driven farther into the body. As the slot is shallower, the blade is forced out as it advances, thus increasing its diameter; it may then be sharpened by grinding to size. The side of the slot is cut at an angle to hold the blade solidly and prevent any tendency it might have to draw away from its seating when the reamer is cutting. The body of the reamer is not hardened; the blades are machined to size, hardened, driven into place and ground to size. If the reamer is of the form known as *fluted reamer*, the teeth may be backed off for clearance as already described.

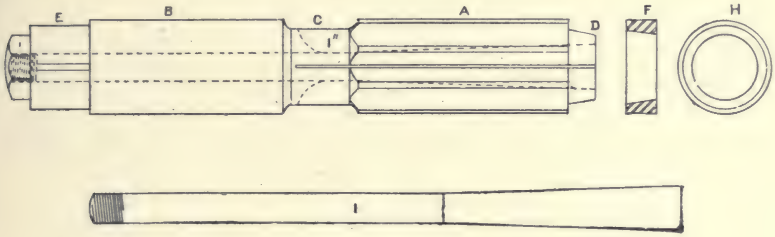


Fig. 47.

Adjustable Reamers are made of a form that allows them to be adjusted to a varying size of parts of machines where interchangeability is not essential. Fig. 47 shows the cheapest form of adjustable reamer; this form is sometimes objected to because it does not expand or contract uniformly its entire length; for ordinary work, however, it is very satisfactory, if used for a limited range of sizes.

Stock should be selected at least $\frac{3}{32}$ inch larger than finish size. After carefully centering and squaring the ends, a chip should be turned the entire length of the piece. It should then be drilled, and the taper hole reamed for the expansion plug. When drilling the outer end, the blank should run in the steady rest; the hole in the *shank* end should be drilled to the proper depth with a drill $\frac{1}{32}$ inch *larger* than the straight stem of the expansion plug. The end should be chamfered to a 60° angle to run on the lathe center when turning and grinding. The piece may be reversed and the opposite end drilled and reamed with a taper reamer; this end should be chamfered also to a 60° angle. Fig. 48 shows a sectional view of the blank drilled and reamed, and the ends of the hole beveled.

The reamer may now be turned .020 to .025 inch above finish sizes on A and B, while C and D may be turned to finish sizes, and the size stamped at C. The end E may be milled square for a wrench, the grooves milled and the reamer split, in order that the size may be altered with the expansion plug.

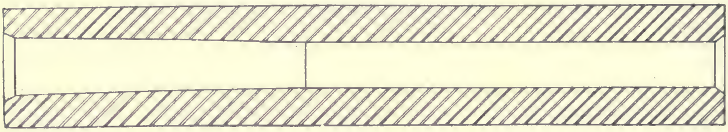


Fig. 48.

When splitting the reamer, a metal slitting saw of the required thickness (usually $\frac{1}{16}$ inch) should be used. The saw cut should not extend to the end of the reamer, but a small portion should be left solid to prevent the reamer from springing when hardening. The circular saw leaves a cut at the end of the shape shown in Fig. 49, which would be extremely difficult to part after hardening. In order that the thin partition of stock may be easily severed with an emery wheel, the slot may be finished, as shown in Fig. 50, with a hand hack saw.

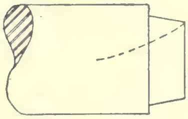


Fig. 49.

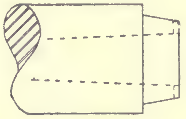


Fig. 50.

The expansion rod I, Fig. 47, should be turned to fit the taper in the reamer, the straight end should be $\frac{1}{32}$ inch smaller than the hole running through the reamer, and should be threaded on the end for a nut to be used in drawing the rod into the reamer. The collar shown at F and H should have a taper hole fitted to the tapered end of the reamer. The outside diameter of collar should be a trifle smaller than the hole to be reamed; this collar, when forced onto the end of the reamer, holds it in place. In order to increase the size of the reamer, the collar may be driven back a trifle and the rod drawn in by means of the nut.

After the reamer is hardened and tempered, the thin partitions left at the ends of the slots may be ground away with a beveled emery wheel, the rod inserted, the collar forced on the end, the reamer ground to size, and the teeth backed off for clearance.

TAPER REAMERS.

If a taper reamer is intended for finishing a hole, the same general instructions may be followed as for *fluted hand reamers*, except that instead of being straight, the body, or cutting part, is tapered.

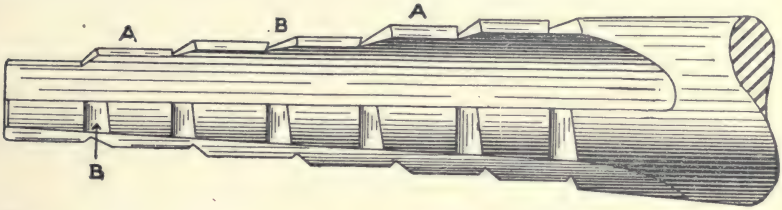


Fig. 51.

Roughing taper reamers are frequently made in the form of a stepped reamer, or it might be called a multiple counterbore, since each step acts as a pilot for the next larger step, as shown in Fig. 51. The steps A are turned straight, each one correspondingly larger than the preceding. The cutting is done at the end of the step B, which must be given clearance; this is ordinarily done with a file. The reamer may be given four cutting edges; these should be cut with a milling cutter intended for milling the flutes of reamers. The number of the cutter selected will depend on the form and amount of taper of the reamers. It is advisable to neck down into the reamer $\frac{1}{32}$ inch at the end of each step; this may be done with a round nose tool, or a cutting-off tool having its corners slightly rounded. The necking facilitates the filing of the cutting edges, and also allows the emery wheel to traverse the entire length of each step when grinding to size after hardening.

Roughing reamers are sometimes made of the form shown in Fig. 52. The left-hand thread cut the entire length of the cutting portion breaks the chips into short lengths, and greatly increases the cutting qualities. After turning the tapered part to a size that allows for grinding, the lathe may be geared to cut a four-pitch thread. The threading tool should be about $\frac{1}{16}$ inch thick at the cutting point, and have sufficient clearance to prevent the heel dragging when the tool is cutting. The corners should be slightly rounded in order to reduce the tendency of cracking when the reamer is hardened. The thread should be cut to a depth of from $\frac{1}{64}$ to $\frac{1}{32}$ inch. After threading, the flutes may be cut, the reamer hardened, and the temper drawn to a light straw.

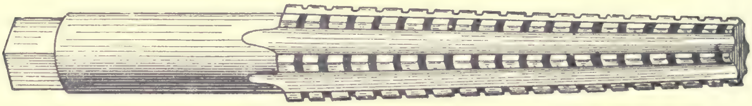


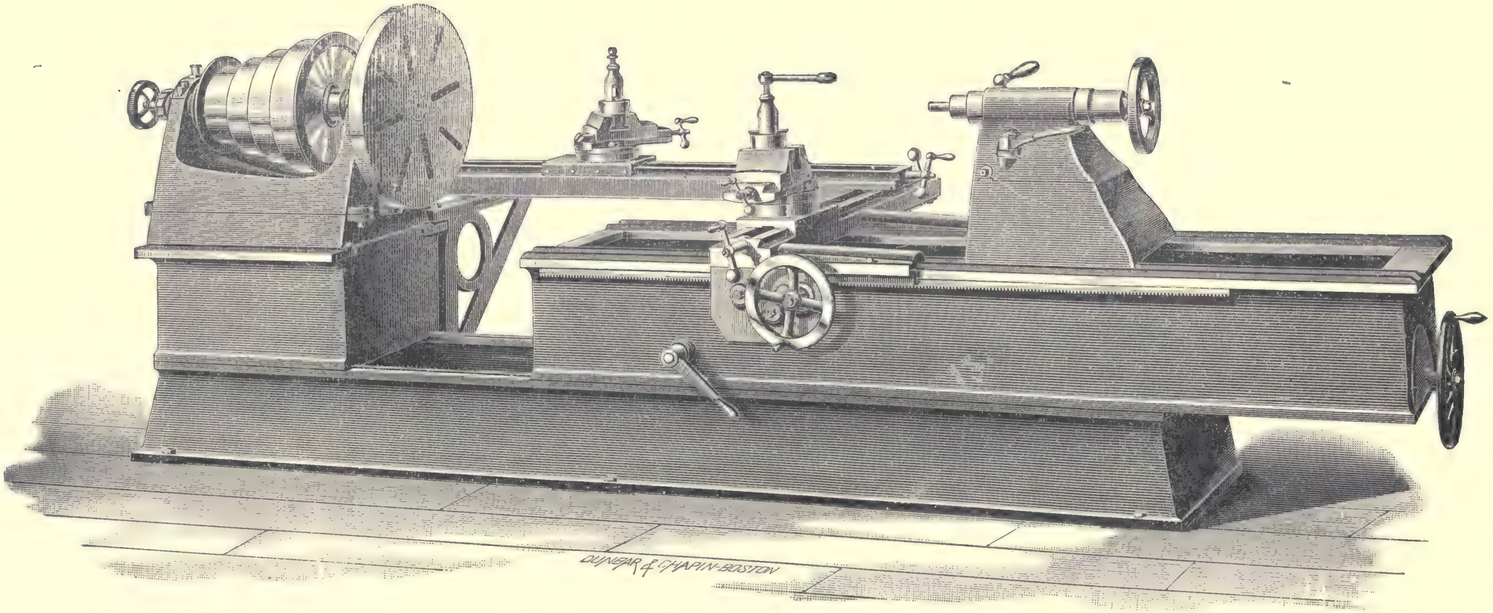
Fig. 52.

When grinding a *taper reamer* the proper clearance is given to the tooth back for a distance of $\frac{3}{64}$ inch from the cutting edge, the balance of the tooth is given a greater amount of clearance, as shown in Fig. 53.

Shell Reamers. As a matter of economy, the larger sizes of reamers are sometimes made in the form of shell reamers, as shown in Figs. 54 and 55. As several reamers may be used on the same arbor, there is quite a saving in cost of material.

The following table gives the size and length of shell reamers from one inch to three inch diameter, together with the size of holes, and width and depth of tongue slot.

			Tongue Slot.	
Diameter.	Length.	Size of Hole.	Width.	Depth.
$1''$ to $1\frac{1}{4}''$	$2\frac{3}{4}''$	$\frac{5}{8}''$	$\frac{1}{4}''$	$\frac{1}{4}''$
$1\frac{5}{16}''$ to $1\frac{5}{8}''$	$3''$	$\frac{3}{4}''$	$\frac{5}{16}''$	$\frac{5}{16}''$
$1\frac{11}{16}''$ to $2''$	$3\frac{1}{2}''$	$1''$	$\frac{3}{8}''$	$\frac{5}{16}''$
$2\frac{1}{16}''$ to $2\frac{1}{2}''$	$3\frac{3}{4}''$	$1\frac{1}{4}''$	$\frac{1}{2}''$	$\frac{3}{8}''$



GAP LATHE.
Fay & Scott.

After drilling a hole $\frac{1}{16}$ inch smaller than finish size, the blank should be placed on a mandrel and a heavy chip taken to remove all the original surface. It should then be annealed.

After annealing it may be placed in a chuck on the lathe and the hole bored .005 inch smaller than finish size. After putting on a mandrel, the ends should be faced to length and the outside diameter turned, leaving .010 to .015 inch on the cutting part for grinding. The balance of reamer should be turned to size. If it is to be a *rose reamer* the edge should be chamferred the proper amount.

The reamer should be held in a chuck on the spiral head spindle in the milling machine, and the tongue slot cut. In order to get the slot central with the outside of the reamer, a cutter somewhat narrower than the desired slot should be used, which should be set as centrally as possible by measurement, a cut taken, the spiral head turned one-half way round and another cut taken; the width of the slot should be measured, and the saddle of the machine moved by means of the graduated adjusting screw one-half the amount necessary to make the slot of the right width. The reamer may now be placed on a mandrel between centers on the milling machine, and the grooves cut.

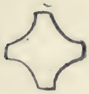


Fig. 53.

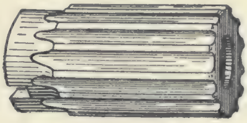


Fig. 54.

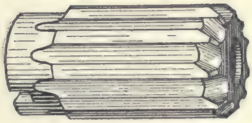


Fig. 55.

The reamer should be heated for hardening in some receptacle in order that the fire may not come in direct contact with it; when it reaches a *low uniform* red heat it may be placed on a wire bent in the form of a hook, and plunged in the bath; it should be worked up and down rapidly until all trace of red has disappeared. When cold it may be heated to prevent cracking from internal strains; if it is to be a rose reamer it may be left *dead* hard, if a fluted reamer the temper should be drawn to a straw color. The hole should be ground to fit the shank on which it is to be used, or a plug gauge, if there is one for the purpose. The reamer may then be placed on a mandrel and ground according to directions given for grinding reamers.

The holes in *shell reamers* are sometimes made tapering — the end of the arbor being made of a corresponding taper — to avoid the necessity of grinding the holes, as any slight change in the size resulting from hardening would be compensated for by the taper hole.

Arbors for Shell Reamers are made as shown in Fig. 56. The shank B and end A to receive the reamer, are made in one piece. The collar C having two tongues to engage in the slots in the reamer, is made of tool steel; the hole is made of a size that allows it to slide over A. When in position a hole is drilled through both collar and arbor and the pin D driven in. When making the collar the hole is drilled and reamed; it is placed on a mandrel, the ends faced to length, and the collar turned to proper diameter. It is then removed from the mandrel and the tongues milled. While doing this the collar is held in the chuck on the spindle of the spiral head and a side milling cutter is used. One side is milled, the spiral head spindle turned one-half revolution, and the opposite side milled; the thickness is measured and the saddle moved enough to bring the tongues to the required thickness when the finish cut is taken on each side. After putting on an arbor and drilling the pin hole, the collar may be removed and spring tempered. It may now be placed on the arbor and the pin driven in place.

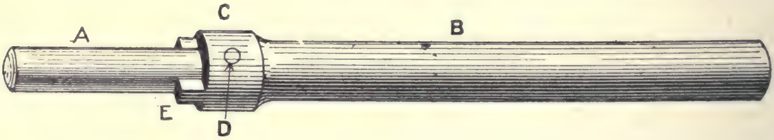
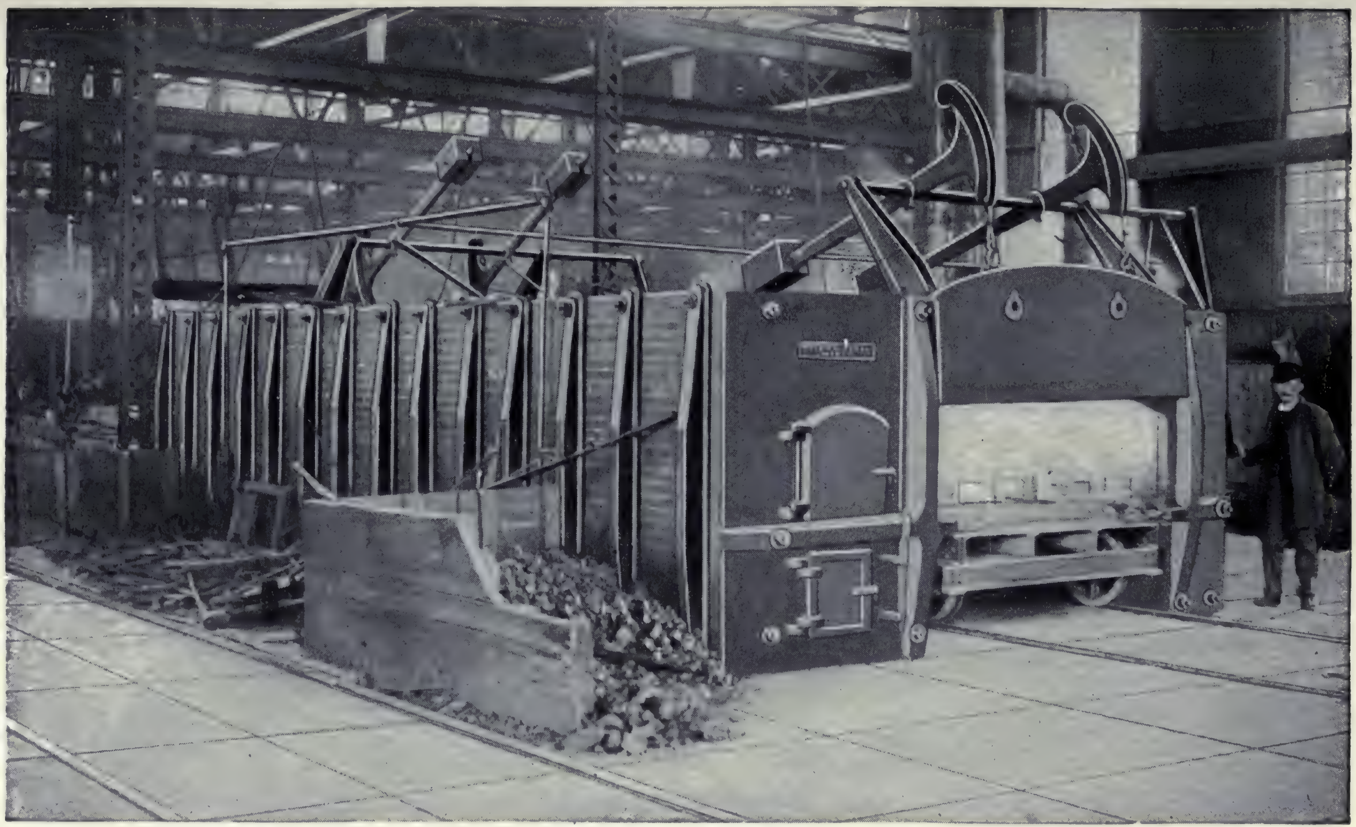


Fig. 56.

When the hollow mill is made with a taper hole, the arbor is made with the end A of a corresponding taper. Otherwise the construction would be the same as for hollow mills having straight holes.

Formed Reamers are used for holes of an irregular shape, or rather of a shape neither straight nor tapering. They are used



STEEL CASTING ANNEALING FURNACE.

Rockwell Engineering Co.

chiefly by gun makers in reaming the end of the gun barrel for the shell, and are termed, when used for this class of work, *chambering reamers.*

It is essential when making this class of reamer, that the stock be rough turned a little above finish size and then annealed. Reamers of this form are accurate as to size and shape, consequently it is customary to use a gauge. This is generally a piece of steel having a hole of the proper form reamed in it, after which the stock is cut away on one side, leaving a trifle more than one-half of the hole as shown in Fig. 57.

To make the reamer blank fit the gauge the operator must understand the use of hand turning tools, as most shapes must be made with these tools. The teeth must be cut with a milling cutter of small diameter following the different shapes of the reamer in order to have the top of the land of as uniform a width as possible. After cutting, the teeth may be backed off for clearance with a file, taking care not to remove any stock at the cutting edge.

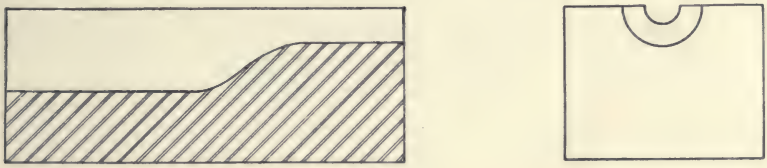


Fig. 57.

When hardening, heat very carefully in a tube until the reamer is of a *low* uniform red heat; it should then be plunged in a bath of lukewarm brine. It may be brightened and the temper drawn to a light straw. After hardening it should be tried in the gauge, and any high spots removed by oilstoning.

If a large number of reamers of one form are to be made, the grinding machine may be rigged with a form which makes it possible to grind many of the shapes in common use, but some shapes will be found quite impracticable to grind, consequently the above method of fitting before hardening must be adopted. Excellent results are obtained by hardening by the " Pack Hardening " process.

Reamer Holders. On account of the uncertainty of exact alignment of every part of a screw machine or turnet lathe, it is desirable to use a holder for the reamer that allows it to properly align itself. The form of holder shown in Fig. 58 is in common use and gives excellent results. It consists of the body A which has a hole drilled and reamed its entire length; the hole must be somewhat larger than the shank of the reamer, $\frac{1}{16}$ inch being considered sufficient. The center B of tool steel should be (after hardening) .010 to .015 inch larger than the hole in the holder; the point should be ground to a 60° angle, and the straight part ground to a forcing fit in the holder. After being forced to position a hole may be drilled through the holder and center, and the pin C driven in to keep the center from being pressed back by the reamer when in operation. A pin should be put through the holder at D; a hole $\frac{1}{16}$ inch larger than the pin should be put through the reamer shank at this point. This pin is simply to prevent the reamer from turning when it comes in contact with the work. The coil springs E E hold the reamer in position to enter the hole, and the proper tension is given by means of the screws F F.

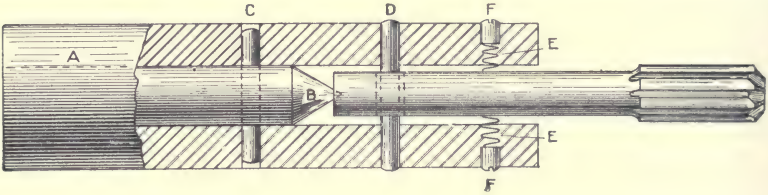


Fig. 58.

ARBORS.

Mandrels. The ordinary taper arbor, known as the mandrel, is in common use in most machine shops. Up to and including $1\frac{1}{2}$ inches diameter, mandrels are made of tool steel, hardened all over and ground to size. Some tool makers advocate making all mandrels up to 4 inches diameter in this way; others prefer hardening the ends B B (Fig. 59), leaving the center A soft, while others maintain that for mandrels above $1\frac{1}{2}$ inches diameter, machinery steel is most satisfactory if thoroughly case hardened.

When making mandrels of tool steel that are to be hardened the entire length, it is not necessary to use the best quality of steel, as a lower grade may be used if it will harden well. Select stock somewhat larger than finish diameter, say $\frac{1}{16}$ inch for sizes up to $\frac{1}{2}$ inch; $\frac{1}{8}$ inch for sizes up to 1 inch; $\frac{3}{16}$ inch for sizes up to $1\frac{1}{2}$ inches, and $\frac{1}{4}$ inch for sizes above. Take a chip off the outside sufficiently heavy to remove all scale, yet leaving $\frac{1}{32}$ inch for a finish cut on sizes up to $\frac{1}{2}$ inch and correspondingly more for the larger sizes. It should now be annealed, preferably in the annealing box. The ends should be countersunk deeper in mandrels than in tools where the centers are not used after they are completed, in order that the centers may not be mutilated when driven in or out of the work. The centers should either have an extra countersink, as at A in Fig. 60, or else the cut should be recessed as at B in Fig. 61.

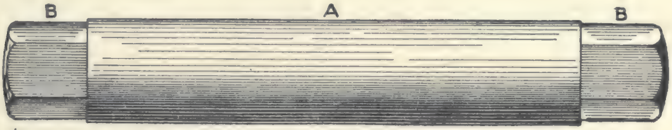


Fig. 59.

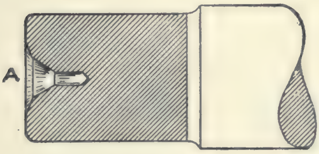


Fig. 60.

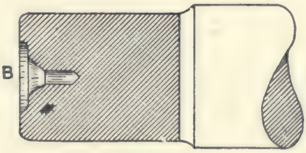


Fig. 61.

The ends B B, Fig. 59, should be turned to size, the corners slightly rounded, and the flat spots for the dog screw milled or planed. The body of the mandrel should be turned somewhat larger than finish size; those smaller than $\frac{1}{2}$ inch should have an allowance of .015 inch; from $\frac{1}{2}$ to 1 inch an allowance of .020 to .025 inch; over 1 inch an allowance of .025 to .030. As the length of mandrels larger than 2 inches diameter does not increase in proportion with the diameter, the amount given will generally be sufficient if proper care is used when hardening. The size should be stamped on the end next to the large end of body.

Before hardening, the centers should be re-countersunk to true them; for this operation it is best to use a special countersink having an angle of 59° instead of the regular 60° tool, as it facilitates the lapping of the centers to a 60° angle after hardening, due to the unequal amount of grinding caused by the shape of the countersinking.

If a blacksmith's forge must be used when heating the mandrel for hardening, the fire should be large enough to heat the piece evenly; it is advisable to heat it in a tube. More uniform results can be obtained from a muffler furnace than in the open fire. In either case the piece should be turned frequently, to insure an even heat. To dip in the bath, a pair of tongs of the shape shown in Fig. 62 should be used, so that the bath may come in contact with both centers. The tongs should grapple the mandrel at the large end, in order that the small end may be harder; it should be worked up and down rapidly in the bath to insure uniform results. A bath of brine will be found very satisfactory for this work.

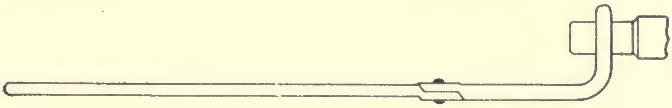


Fig. 62.

A mandrel larger than 1 inch diameter should be removed from the bath as soon as it ceases *singing*, and held in a tank of oil until cold. The ends should be brightened and drawn to a deep straw color, in order to toughen them so that they will not break or chip off when driven. Mandrels smaller than $\frac{3}{4}$ inch should have the temper drawn to a light straw color the entire length of body.

After hardening, the body of the mandrel should be cleaned with a coarse emery cloth, to remove the scale or grease which would glaze the emery wheel. It should then be tested between centers to see if it has sprung more than will grind out before it reaches the proper size.

The centers should now be lapped, to insure proper shape and alignment. The lap may be a piece of copper of the proper shape (60°) charged with diamond dust or emery. After lapping, the centers should be thoroughly cleaned with benzine. (When using benzine do not allow it to get near a flame of any kind.)

Examine very carefully the condition of the centers of the grinder, as the truth of the mandrel depends in a great measure on their condition. A mandrel may be ground in a lathe having a grinding attachment or in any universal grinder. Better results can be obtained, however, if ground in some form of grinder having a stream of water to keep the work from heating, as heat is likely to spring the piece, especially if it does not run true, thus making the grinding heavier on one side than the other. If a dry grinder must be used, do not force the grinding fast enough to heat the piece. The mandrel should be ground to within about .005 inch of size with a coarse wheel free from glaze, and then finished with a fine wheel.

The amount of taper varies: some manufacturers prefer .0005 inch taper per inch, while others make them of .001 inch taper for every inch of length, claiming that if a piece having a long hole is to be held on *any* taper mandrel it will not fit at the end nearest the small end of mandrel, consequently the turned surface will not be true with the hole; also that for such work a mandrel should be made for the job having a body nearly or quite straight. They claim that the mandrel should be made to taper .001 inch for every inch of length, in order that it may be adapted to a greater range of work.

Mandrels with Hardened Ends. When making a mandrel whose ends are to be hard and body soft, follow the instructions given for hardened mandrels, except that a larger amount of stock should be left on the body. The ends should be hardened for a distance that insures the *centers* being hard; this can be accomplished by heating one end at a time to a red heat, and inverting under a faucet of running water. As the center is uppermost, the water can readily enter it, forcing the steam away. After drawing the temper of the ends and lapping the centers, the body may be turned to size. The centers of the lathe should be carefully trued before starting this operation. If the body of the mandrel is left .008 inch to .010 inch larger after turning, and then ground to size, the results will be surer; but with *extreme care* a very satisfactory job may be done by the method described.

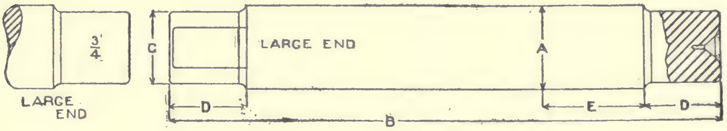


Table of Dimensions of Mandrels to 1 Inch.

A	B	C	D	E	F
$\frac{1}{4}$	$3\frac{3}{4}$	$\frac{7}{29}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{8}$
$\frac{5}{16}$	4	$\frac{9}{32}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{32}$
$\frac{3}{8}$	$4\frac{1}{4}$	$\frac{11}{32}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{16}$
$\frac{7}{16}$	$4\frac{1}{2}$	$\frac{13}{32}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{7}{32}$
$\frac{1}{2}$	5	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{4}$
$\frac{9}{16}$	$5\frac{1}{4}$	$\frac{1}{2}$	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{9}{32}$
$\frac{5}{8}$	$5\frac{1}{2}$	$\frac{9}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{5}{16}$
$\frac{11}{16}$	$5\frac{3}{4}$	$\frac{5}{8}$	$\frac{13}{16}$	$\frac{15}{16}$	$\frac{11}{32}$
$\frac{3}{4}$	6	$\frac{11}{16}$	$\frac{7}{8}$	1	$\frac{3}{8}$
$\frac{13}{16}$	$6\frac{1}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{16}$	$\frac{13}{32}$
$\frac{7}{8}$	$6\frac{1}{2}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{1}{8}$	$\frac{7}{16}$
$\frac{15}{16}$	$6\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{3}{16}$	$\frac{15}{22}$
1	7	$\frac{15}{16}$	1	$1\frac{1}{4}$	$\frac{1}{2}$

Machinery Steel Mandrels. With the exception of hardening, the instructions given for making mandrels of tool steel apply to those made of machinery steel. It is necessary to *case harden* mandrels made of machinery steel, using the method already described. The work should be run in the fire from seven to ten hours after the box is red hot throughout; dip in a a bath having a jet of water coming up from the bottom to force the steam away from the work, to avoid soft spots. It is not necessary to draw the temper, as the hardening does not extend far below the surface.

Expanding Mandrels. There are several forms of expanding mandrels in common use. One form has a sleeve with a taper hole fitting on a mandrel that has a corresponding taper; the sleeve is split to allow it to expand as it is forced on the mandrel.

It is not advisable to give the mandrel very much taper, because a heavy cut with the pressure toward the small end would crowd the sleeve toward that end, thereby releasing the work. Ordinarily a taper of $\frac{1}{2}$ inch to the foot will give good results.

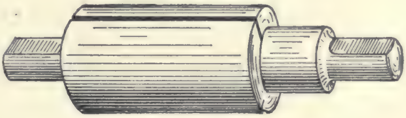


Fig. 63.

It is obvious that the range of adjustment for a sleeve as described is small, but sleeves of different diameters may be fitted to the same mandrel, the thickness of wall being increased to give the desired size. The diameter of the sleeve should be such that the work may enter without forcing, the tightening being accomplished by forcing or driving the sleeve toward the large end of the mandrel.

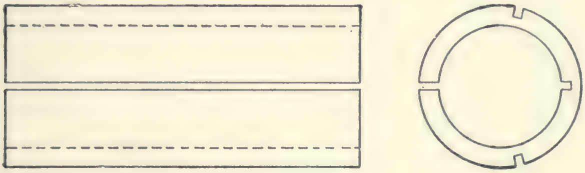


Fig. 64.

If a sleeve is required for a special sized hole, and is to be used but a few times, and through a limited range as to size, it may be made of cast iron. A hole is bored in it corresponding in size and taper to its mandrel; the hole should be made to allow the small end of the mandrel to go through and be flush with the end of the sleeve. The sleeve should be forced on the mandrel and turned to size; the outside diameter should fit the hole in the piece to be machined when the sleeve is at the small end.

In order that the sleeve may be expanded it is split as shown in Fig. 64. This should be done in the milling machine, the sleeve being held by the ends in the vise and the cut made with a metal slitting saw. When the sleeves are intended for permanent equipment it is good practice to make them of either machinery steel or tool steel,— if made of the former they may be case hardened, if of the latter they may be hardened and spring tempered. In either case the hole should be .010 inch small, and the outside diameter .020 to .025 inch large, and ground to size after hardening. A method of splitting the sleeve for a more uniform expansion is shown in Fig. 65; small sizes have four cuts for adjustment, while the larger sizes have six or eight.

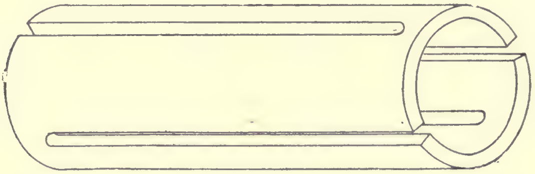


Fig. 65.

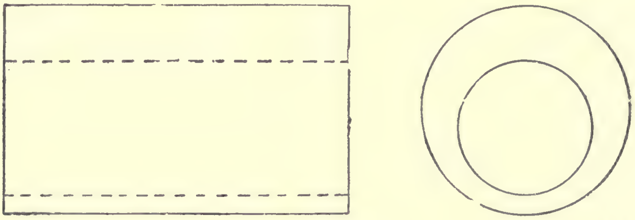


Fig. 66.

On account of the peculiar construction of the sleeve shown in Fig. 65 it must be held while grinding the hole, so that it will not spring. To do this the sleeve may be placed in a hole in a collar and held by several drops of solder so placed as to hold it rigidly in position. In order that the solder may stick, the outside of the sleeve must be brightened. When soldered securely the collar may be placed in the chuck on the grinding machine and the hole ground to the desired size, after which it may be heated to melt the solder, and the sleeve removed from the collar. It can then be placed on the mandrel and the outside diameter ground to the proper size.

Eccentric Arbors. Arbors are made eccentric in order that the outside of a piece of work may be made eccentric to the hole running through it, as shown in Fig. 66.

When making an eccentric arbor the general directions given for making mandrels may be followed, except that the centers should be quite small. The mandrel should be placed in a V block or in a pair of centers, and by means of a surface gauge, the needle of which has been set at the exact height of the center, a line may be drawn, as shown in Fig. 67, across each end of the mandrel. The mandrel may now be turned so that the line will be vertical; the point of the surface gauge may be raised to give the required amount of eccentricity, and a line, as shown in Fig. 68, scribed on each end. The ends should be prick punched where the lines intersect, and drilled and countersunk at this point.

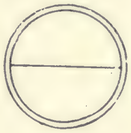


Fig. 67.

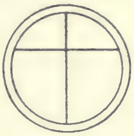


Fig. 68.

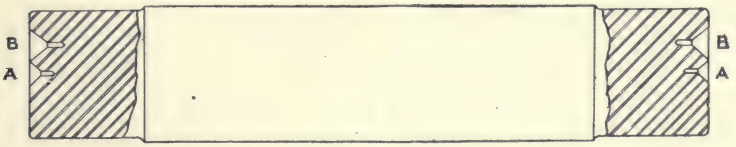


Fig. 69.

After hardening, both pairs of centers should be lapped to shape. The centers marked A A (Fig. 69) must be used when grinding the mandrel to size or in turning work which is to be concentric with the hole, while the centers B B are used when turning the eccentric parts. This method of laying off and drilling the eccentric center may not give the necessary accuracy; in such case a jig must be used in drilling the center holes. A suitable jig is shown in Fig. 70. The ends of the arbor must be turned to fit the hole A, Fig. 70, in the jig, which is a collar having a straight hole through it. A piece of steel, which is a forcing fit in this hole, has a hole the size of the centering drill laid off with the proper amount of eccentricity. This piece of steel is forced to the center of the collar, as shown at B. A straight line should be drawn across the collar and down the beveled edges, as shown at C. A line should now be scribed the entire length of the mandrel, which should be set to match the line on the jig, which may be secured in its proper position by means of the set screws.

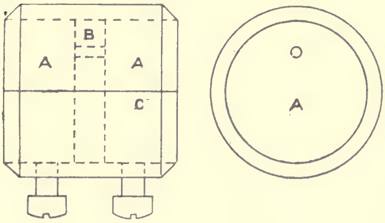


Fig. 70.

For machining a cylindrical piece having a hole through it to receive an arbor, and the faces of the piece not parallel, as shown in Fig. 71, it is well to use a mandrel having two sets of centers, as shown in Fig. 72, one of which, A A, are the regular centers, while the eccentric centers, B B, should be equidistant from the regular centers, but on opposite sides.

Milling Machine Arbors. Arbors for milling machines should be made from steel strong enough to resist (without twisting or springing) the strain caused by tightening the nut. When a limited number of arbors is made, tool steel is generally used; but for many milling machines, necessitating a great many arbors, a lower priced steel having the necessary stiffness is selected.

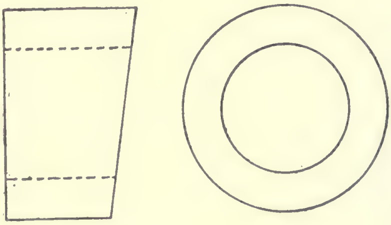


Fig. 71.

After centering and squaring the ends, a chip is turned the entire length of the piece, to remove all the outer surface. The ends D and C, Fig. 73, are next turned to size, and the tenon milled to the desired dimensions; when milling for the tenon, the arbor should be held between centers, and the cutting done with an end mill of the form shown in Fig. 74; the circumference of the cutter, leaving the proper shape at end of tenon. The centers should be hardened, and the temper drawn to a straw color. If the projection on the end of the arbor at C, Fig. 73, is to be run in a socket in the tail block of a milling machine, it must be hardened the entire length, in which case the thread for the nut should be cut before hardening the end. If a lathe having a taper attachment is used, there is no particular method of procedure other than that the arbor should be roughed nearly to size before either the taper or straight end is finished. It will save time, however, if the straight end A, Fig. 73, is roughed first, then the taper B roughed and finished, after which the shoulder E and the straight part A may be turned to size and finished. If the projection C is to run in a socket, it should be turned .010 or .015 inch above finish size, and ground to the proper dimensions.

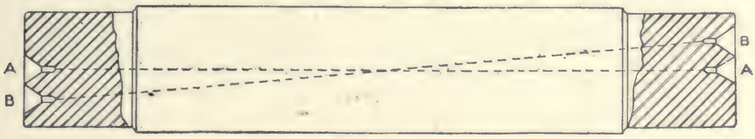


Fig. 72.

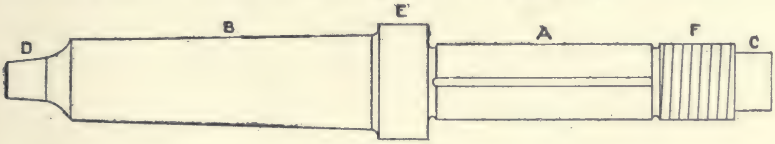


Fig. 73.

If it is necessary to use a lathe having no taper attachment, the necessary taper must be obtained by setting over the tail block. In this case it is better to turn and fit the taper first. If the taper were turned to finish size after finishing the straight part, the centers would become changed to a degree that would throw the arbor out of true. These instructions should be followed wherever a straight and taper surface are to be turned on the same piece of work, in a lathe having no other means of turning tapers except by setting over the tail block.

Milling machine arbors should have a spline slot cut the entire length of the part that is to receive the cutters; this can best be done in a shaper. Before putting the arbor in the shaper vise a hole should be drilled close to the shoulder for the tool to run into; the drill used should be about $\frac{1}{32}$ inch larger in diameter than the thickness of the splining tool, and the hole drilled a trifle deeper than the slot to be cut. When the arbor is placed in the vise a piece of sheet brass or copper should be placed between the arbor and the vise jaws to prevent bruising the arbor.

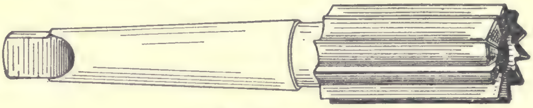


Fig. 74.

Where *extreme* accuracy is required, it is advisable to leave the straight and taper parts a few thousandths of an inch above size and grind to size all over after the spline cut is taken.

The nut is usually made of machinery steel, case hardened. A bar of steel $\frac{1}{16}$ inch larger than finish size of nut is selected, and a piece $\frac{1}{16}$ inch larger than finish length is cut; it is then put in a chuck on the lathe, the hole drilled, and the thread cut; if no tap of the desired size is at hand the thread may be chased. If a tap can be obtained, the thread should be chased nearly to size and finished with the tap; before taking from the chuck the end of nut should be faced and the hole recessed to the depth of the thread for a distance of two threads. After taking from the chuck it should be placed on an arbor having a screw which fits the thread in the nut. The nut should be turned to size and length, and the two opposite sides milled to receive the wrench used in tightening. Fig. 75 gives two views of the nut. It should be made and case hardened before the thread is cut on the arbor, in order that the thread on the arbor may be made to fit the nut. Milling machine arbor nuts should fit the thread on the arbor in such a manner that they may be turned the entire length of the thread without the aid of a wrench, yet not be loose.

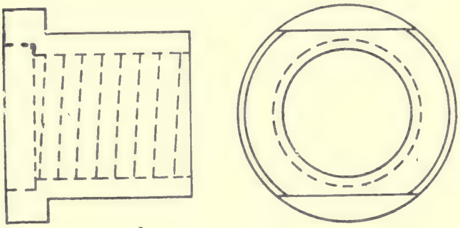


Fig. 75.

TAPS.

When making taps $\frac{1}{4}$ inch diameter and smaller, the threads are often cut with screw dies, of which there are two styles. The form of screw plate shown in Fig. 76 is termed a *jam die plate.* With this form the die is opened to allow the wire to pass through until it is even with the outside edge of the die, which is now forced into the wire by means of the adjusting screw A; the screw plate is revolved until a thread the desired length is cut. This operation is continued, the die being closed a trifle each time until the desired size is obtained. The method taken of gauging the correct size varies in different shops; if only one is made, the tops of the threads are measured with a micrometer caliper; but for many taps of the same size, such as for sewing machines, guns and bicycles, a sizing die is used to give the threads an exact size. The threads are cut to within a few thousandths of an inch with the die plate, and finished with the sizing die. One form of sizing die is shown in Fig. 77.

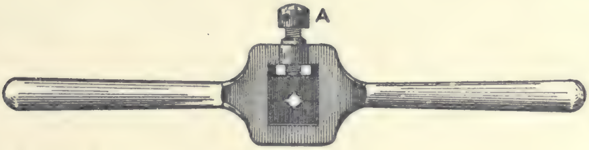


Fig. 76.

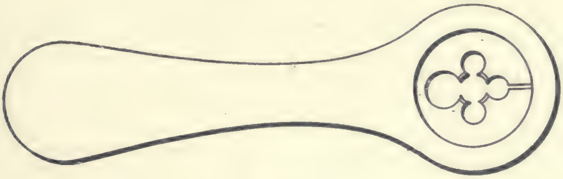


Fig. 77.

Where a great many taps of a size are cut, it is customary to use several dies of different sizes, one of which (the finishing die) is always made adjustable. The roughing dies may be made solid or adjustable, but the finishing must be adjustable for wear, or when it is found desirable to change the size of the taps. These dies are sometimes held in separate holders of the form shown in

Fig. 77, but a very convenient form of holder is shown in Fig. 78. If all the dies are in one holder they do not become scattered around the shop. When making many taps at a time, the work can be done better and cheaper if the wire is held in a chuck in a lathe. The die plate should be placed against a drill pad held in the tail spindle of the lathe, in order to insure starting the threads true. The largest die should of course be run on first, the second largest next and so on to the finish die.

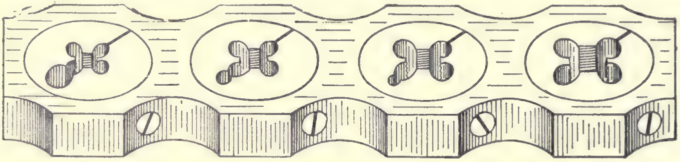


Fig. 78.

For taps up to and including $\frac{1}{4}$ inch diameter, it is customary to use drill rod. The taps should be chamferred for a distance of three or four threads, as shown at A, Fig. 79, in order that the point may enter the drilled hole.

Taps for general use around the shop are often made in sets of three; the first tap to enter the hole is called the taper tap, because of tne long chamferring or taper. The second is known as the plug tap; this tap has the first two or three end threads chamferred, and is used when the screw is to go nearly to the bottom of the tapped hole. The bottoming tap is used when the thread is to go to the bottom of the hole being tapped; the end of this tap is not chamferred. See Fig. 80.

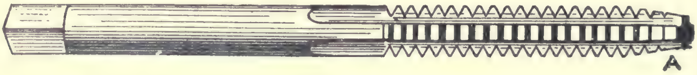


Fig. 79.

Taps larger than $\frac{1}{4}$ inch are made from tool steel. Taps $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter should be made of stock at least $\frac{1}{16}$ inch large; it should be centered quite accurately with a small drill, because a large center hole weakens the tap and increases the liability of its cracking when hardened. After taking a chip sufficiently deep to remove all the outer coating, it should be "box annealed" if possible.

HAND TAPS.

Hand taps are intended for tapping holes by hand and are usually made in sets of three, as previously explained. After annealing, the shank should be turned to size and the square end milled for a wrench. The body should now be turned to size, and the thread cut. Before turning any of the parts to size or starting to cut the thread, be sure that the centers of the lathe are in good condition; the live center should run true, the dead center should fit the center gauge, and be in good shape.

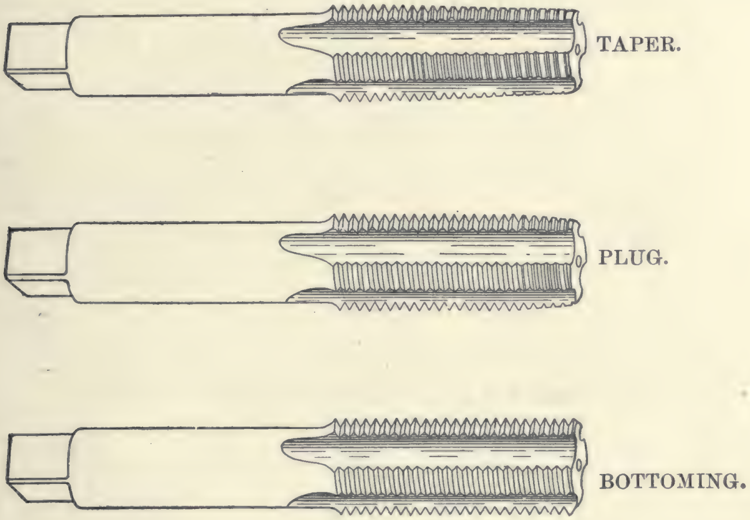


Fig. 80.

It is advisable to cut the tap slightly tapering, the thread being from .0005 to .001 inch smaller at the end toward the shank. This prevents the tap binding when slightly worn, yet it is not tapering enough to affect the accuracy of the thread. The thread tool should be an exact fit to the gauge, and placed in the tool post so that the top of the shank stands about level. The top of blade shown at A, Fig. 81, should be ground parallel with the top of the shank; the cutting point should be set at the exact height of the point of the head center. Many tool makers consider it advisable to rough the thread nearly to size with a single point tool, finishing it with a chaser which may be held in the same holder. A chaser blade is shown in Fig. 82. After the thread is cut to size and the end chamferred, the tap is ready to be grooved in the milling machine. The tap is held between centers and the grooves cut with a cutter especially adapted to the size and style of tap. While the grooves should be cut with a milling machine cutter, it is possible to cut them in a planer or shaper, using a tool of the proper shape. Great care must be used not to stretch the tap by heavy chips, or by using a dull tool.

The grooves cut in taps are ordinarily termed flutes. When making taps for the market it is usual to cut four flutes in all taps up to and including 2½ inches diameter. But when taps are made in the shop where they are to be used, the number and shape of the grooves depend on the nature of the intended work. A tap that is to run through the work without any backing out, can have a different shaped flute from one that is to tap a deep hole in a piece of steel, where it is necessary to reverse the motion of the tap every two or three revolutions to break the chip, and also to allow the lubricant to reach the cutting lips.

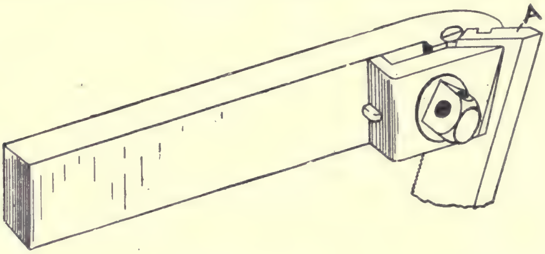
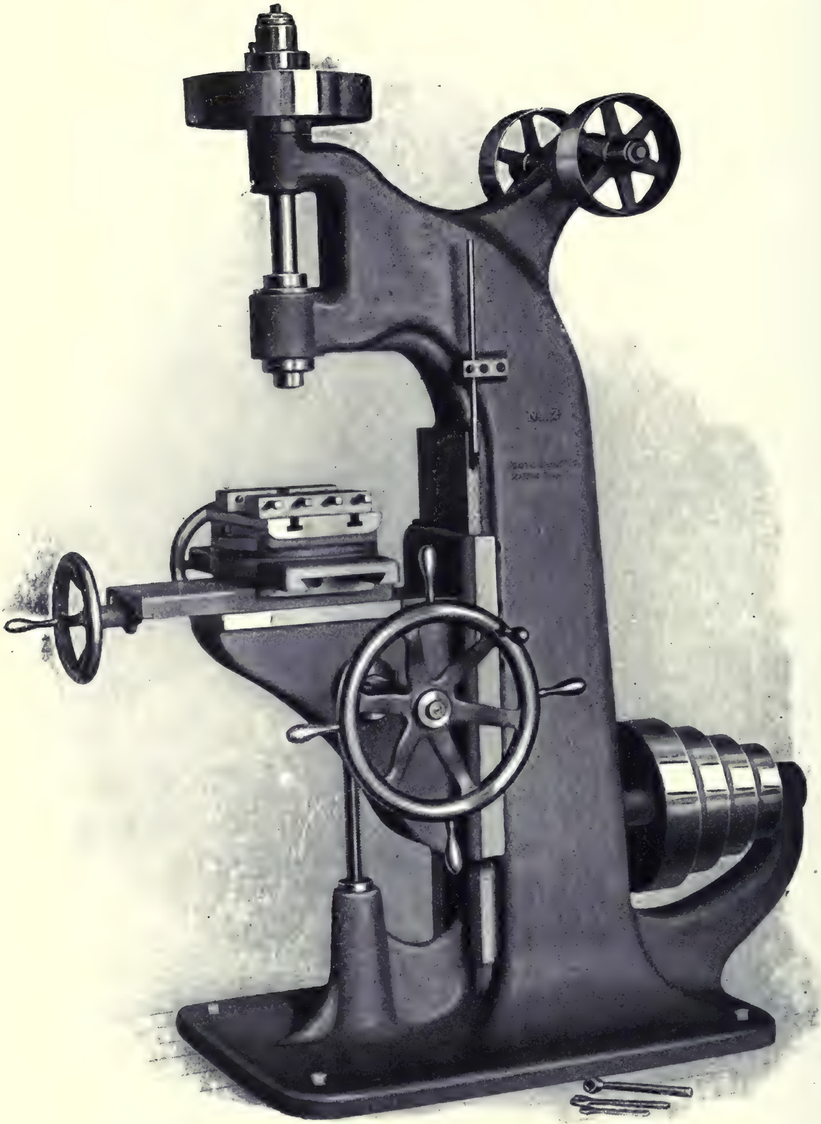


Fig. 81.

While all taps up to and 2½ inches diameter are usually given four straight flutes, spiral flutes are sometimes desirable, especially with small taps for some classes of work. With spiral flutes, it is generally necessary to cut a less number, and as taps are not ground after hardening, there is no objection to giving an odd number of teeth, as in case of a reamer. Three spiral flutes are often cut.

If a tap 1 inch in diameter, having four flutes of the regulation width, were used to tap tubing having thin walls, the tubing



DIE SINKING MACHINE.
Pratt and Whitney Co.

between the lands would have a tendency to close into the flutes of the tap, which might break the tubing. In such a case there should be double the number of flutes, in order to provide enough lands to hold the tubing in shape. If the hole to be tapped has part of its circumference cut away as shown in Fig. 83, more than four lands are necessary.

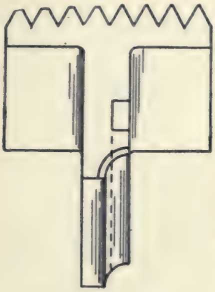


Fig. 82.

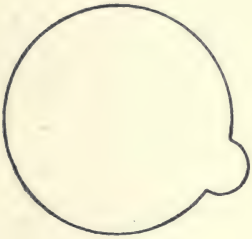


Fig. 83.

However, for general machine shop work four flutes work well in hand taps up to and including 2½ inches diameter. For larger sizes, some tool makers advocate six flutes ; others claim best results from taps having four flutes regardless of size. The class of work and the stock used in the individual shop must determine this.

Forms of Flutes. The most commonly used form of flute is that cut with a convex milling cutter (Fig. 84) for milling half circles. The advantages claimed for this form are: the flutes are of sufficient depth to provide for the chips, and yet leave the lands strong enough; and the form of the back of the land is such that the chips cannot be wedged between the land and the work when the motion of the tap is reversed. The form of groove made with this cutter is shown in Fig. 85. In order to support the tap when starting to cut, and to prevent cutting the hole large at the outer end, hand taps have their lands left wider (as shown at A, Fig. 85) than is the case with machine taps. If the forms

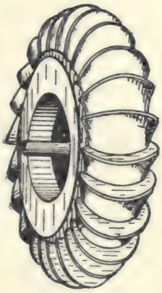


Fig. 84.

of cutter shown in Fig. 85 or Fig. 86 are used, the width of lands as shown at A may be one fourth the diameter of the tap. A Brown & Sharpe Tap and Reamer Cutter is shown in Fig. 86.

Fig. 87 shows a special form of cutter made by Brown and Sharpe. It does not make as deep a groove (Fig. 88) in proportion to the width as a Tap and Reamer Cutter.

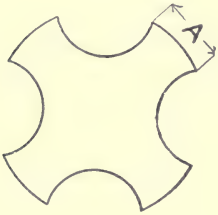


Fig. 85.

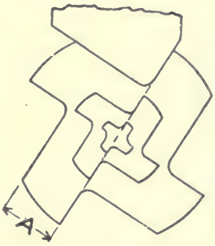


Fig. 86.

After cutting the grooves, the lands should be backed off to give the tap cutting edges; this is usually done with a file. Commence at the heel of the land, A Fig. 89, file the top of the land, and gradually approach the cutting edge, making sure that no stock is removed at that portion; simply bring it to a sharp edge. Enough should be filed off the heel A to make it cut readily, yet not enough to cause it to chatter. The size and number of threads per inch should be stamped on the shank of the tap. If it has a thread differing from that in general use in the shop, that should also be stamped on the shank, as U. S. S., if it is a United States Standard thread.

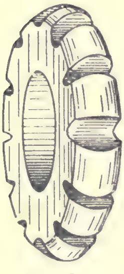


Fig. 87.

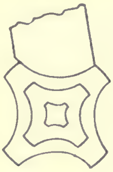


Fig. 88.

The following table gives the number of cutter for different diameters of taps when the form shown in Fig. 87 is used.

No.	1	Cutter	Cuts	Taps			to $\frac{1}{8}$	inch	diameter.
"	2	"	"	"	from $\frac{5}{32}$	inches	" $\frac{1}{4}$	"	"
"	3	"	"	"	" $\frac{9}{32}$	"	" $\frac{3}{8}$	"	"
"	4	"	"	"	" $\frac{7}{16}$	"	" $\frac{5}{8}$	"	"
"	5	"	"	"	" $\frac{11}{16}$	"	" $\frac{7}{8}$	"	"
"	6	"	"	"	" $\frac{15}{16}$	"	" $1\frac{1}{4}$	"	"
"	7	"	"	"	" $1\frac{5}{16}$	"	" $1\frac{5}{8}$	"	"
"	8	"	"	"	" $1\frac{11}{15}$	"	" 2	"	"

Hardening. If but a few taps are to be hardened at a time, it is customary to heat them in a gas jet or an open fire of charcoal or hard coal. It is advisable, however, to heat the taps gradually in a tube. They may be plunged one at a time into the bath a little above the threads. The tap should be worked up and down and around in the bath to prevent soft spots. Taps 1 inch diameter and smaller should be left in the bath until cold; if larger they may be removed from the bath as soon as the singing noise ceases, and immediately plunged in oil and left until cold. For taps less than ¼ inch diameter, the citric acid bath will be found satisfactory; for larger taps use strong brine.

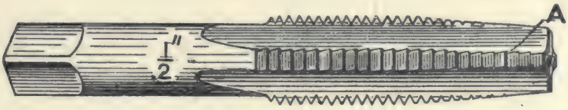


Fig. 89.

To have the tap retain as nearly as possible its size and correctness of pitch, use the "pack hardening" process. Run taps ⅛ inch diameter and smaller, ½ hour after they are red hot; taps ⅛ to ¼ inch diameter, 1 hour; taps ¼ to ½ inch diameter, 1¼ hours; taps larger than one inch diameter, 2 hours. Harden in a bath of raw linseed oil.

Fig. 90.

It is advisable to grind the flutes of the taps with an emery wheel of the proper shape in order to brighten the surface, so that the color may be readily seen when drawing the temper. It also sharpens the cutting edges and breaks the burrs that have been thrown between the teeth when cutting the flutes. The temper should be drawn to a full straw color. Much more satisfactory results may be obtained by heating the taps in a kettle of oil, drawing the temper to a point from 460° to 500°, according to the size of the tap and the nature of the stock to be cut.

MACHINE TAPS.

As the name implies, machine taps are intended for screw machines, tapping machines, and lathes. They are held in chucks or collets by their shanks, and are supported firmly. Consequently the lands may be made narrower than those of hand taps to make them offer less surface to the work, thereby reducing the amount of frictional resistance. Also, they may be relieved between the teeth, by filing with a sharp cornered three square file, commencing at the heel of the tooth and filing nearly to the cutting edge.

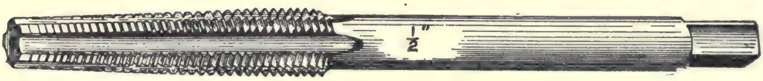


Fig. 91.

It is not good practice to relieve the teeth very much because chips may be drawn between the work and the lands when backing out of the work. When taps are to be used in an automatic tapping machine without reverse motion the shanks are left long as shown in Fig. 90 in order that the nuts may pass over the thread and on to the shank. When this is full the tap is taken from the machine and the nuts removed; this can be readily done as they will pass over the end of the shank.

If a tap is to be used on nuts whose holes are punched to size, much better results are obtained by using a tap having five flutes, as shown in Fig. 91, instead of four. The uneven number of cutting edges reduce the liability of an imperfectly tapped hole, while the extra land furnishes additional support.

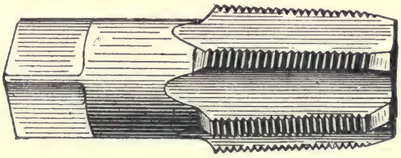
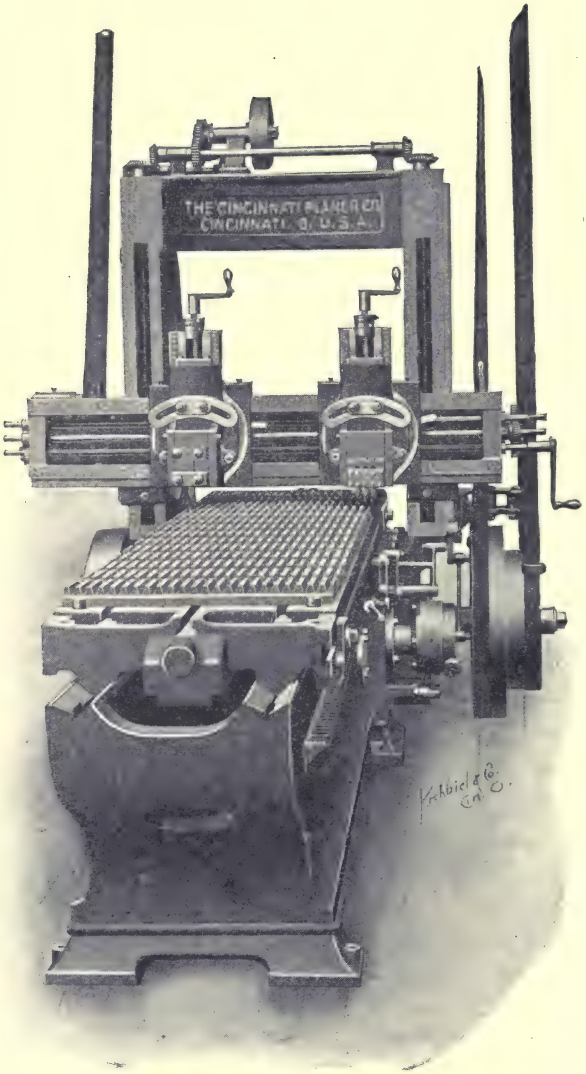


Fig. 92.

Taper Taps. When cutting the threads of a taper tap, Fig. 92, it is necessary to use a lathe having a taper attachment, as the pitch of the threads is not correct if the taper is obtained by setting over the tail stock. Like machine taps, the teeth of a taper must be relieved back of the cutting edge.

In setting the threading tool for cutting taper taps, care



RACK CUTTING PLANER.

should be taken that it is square with the axis of the tap, rather than square with the taper sides.

Screw Die Hobs. Die hobs are finish taps for sizing the thread in screw cutting dies. The several flutes are narrower than those of an ordinary tap and the lands are correspondingly wider. The tap shown in Fig. 93 has eight flutes. The increased number and broader lands support the tap while running through dies whose clearance holes are drilled, in order to remove burrs thrown in the threads when drilling. It is customary to give screw die hobs six to ten flutes.

When hobs are used for solid dies they must be of exact size. When intended for tapping adjustable dies, such as are ordinarily used for cutting threads in screw machine work, the hobs are made from .003 to .005 inch above the size of the screw to be cut. The extra size gives relief to the threads of the die.

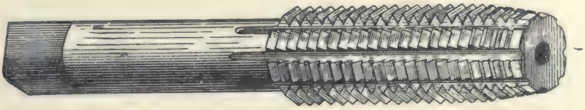


Fig. 93.

While it is generally considered advisable to run one or more taps through a die before the hob, some tool makers consider it better to make a hob that will do all the cutting, claiming that no two taps can be made and hardened so that the pitch will be exactly the same. In such cases a hob (Fig. 94) is made that will cut a full thread by passing through the die.

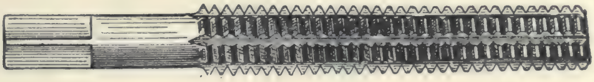


Fig. 94.

Some manufacturers cut the thread tapering for about three-quarters of the entire length of the thread, leaving the balance straight for use in sizing the die. Others cut the thread straight and taper the outside of the thread for three-quarters its entire length. If the threads are cut tapering, they must be relieved back of the cutting edges, as already described.

ADJUSTABLE TAPS.

A solid tap made to cut to exact size, having no leeway for wear, soon becomes too small. This is overcome by making a tap that may be adjusted from time to time. Another reason for making taps adjustable is that the holes may be tapped to fit hardened screws which vary in size on account of having been hardened.

Probably the most common form of adjustable tap is the one shown in Fig. 95. This tap is made in one piece, and then split. It has some means of adjustment whereby the tap may be expanded or contracted through a limited range. This may be accomplished by using a taper bodied screw. The hole to receive the screw should be drilled, tapped and taper reamed, before the tap is turned to size. The thread should then be cut and the taper thread cut on the end at A. There is less tendency to spring when the tap is hardened if the projection shown in Fig. 96 is provided; this may be ground off after the tap is hardened and tempered. After cutting the flutes, the tap may be split in the milling machine using a metal slitting saw; the tap should be held between centers. It is split on two opposite sides, as shown at B, Fig. 95. The splitting should not go to the end of the projection.

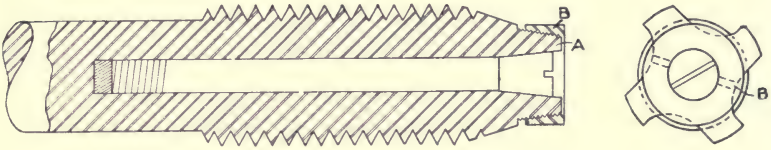


Fig. 95.

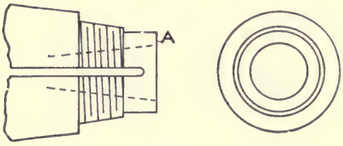


Fig. 96.

For hardening taps "Pack Hardening" is the best method. But, if it is impossible to use this method, heat the tap very carefully in a muffler furnace, or in a tube, having previously plugged the hole for the adjusting screw with fire-clay mixed with water to the consistency of dough. When the tap is heated to the proper degree it should be dipped in a bath of luke-warm brine, and worked up and down rapidly. After hardening, it should be ground in the flutes, and the temper drawn to a full straw color. The projection on the end may be ground off, the taper screw inserted, and the locking nut B, Fig. 95, screwed to place. This nut has a taper thread cut inside to correspond with the thread on the tap at A, Fig. 95. It will be found necessary to cut the taper thread on the tap and in the nut by means of the taper attachment.

Inserted Blade Taps. The first cost of an inserted blade tap may not be much less than that of a solid tap of the same size, yet on account of the comparatively small cost of new blades which can be inserted in the same body, or holder, when the first set becomes worn, this form is very valuable for taps larger than 1½ inches diameter. The tap shown in Fig. 97 may also be used as an adjustable tap. The shank or holder A is made of machinery steel, and the adjusting collars C C are beveled on the inside at one end at an angle corresponding to the angle on the ends of the blades. An angle of 45° will be found satisfactory.

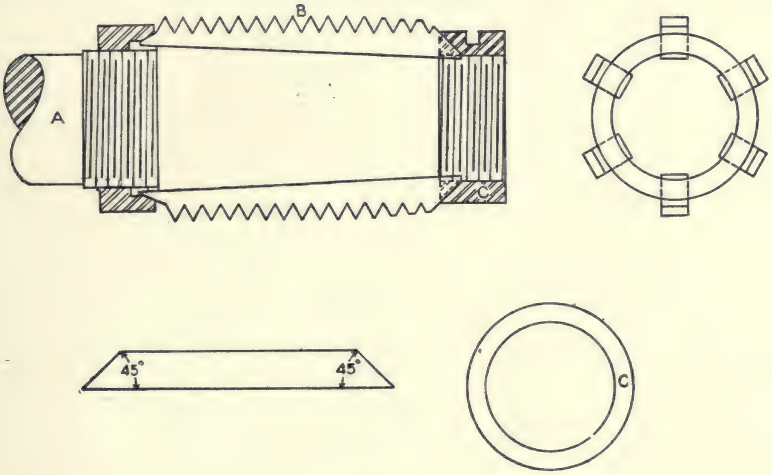


Fig. 97.

After turning the body, or holder to size, and cutting the threads to receive the nuts, the slots for the blades may be milled;

these should be cut deeper at the cutting end in order that any change in the location of the blades may alter the size of the tap. A taper of $\frac{1}{16}$ inch in three inches is ample. If the slots are milled on the universal milling machine, and the tap held in the universal centers the spiral head may be depressed sufficiently to give the desired angle. If a pair of centers of the form shown in Fig. 98 are used they may be held in the milling machine vise at the desired angle. The milling cutter should be set about $\frac{1}{32}$ inch ahead of the center in order that the face of the blade may be milled enough to take any inequality in the teeth at the cutting face of the blade occasioned by the thread tool striking the face when it starts to cut. The amount milled from the face should be just enough to leave the cutting face radial. The blades should be of an exact length and should fit accurately in the slots. A gauge of the form shown in Fig. 99 will insure uniform length. After the blades have been carefully fitted to the slots and to the gauge, they may be inserted in the holder and secured by the nuts as shown in Fig. 97. The outside diameter is then turned about

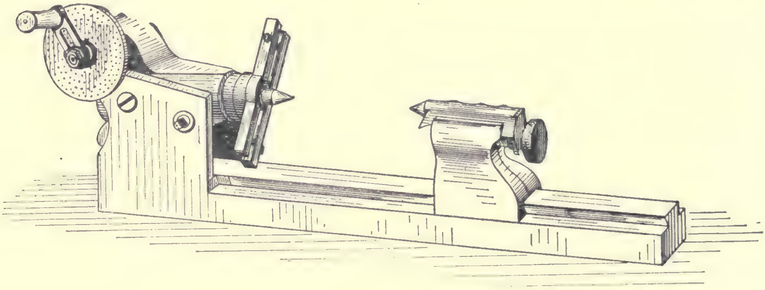


Fig. 98.

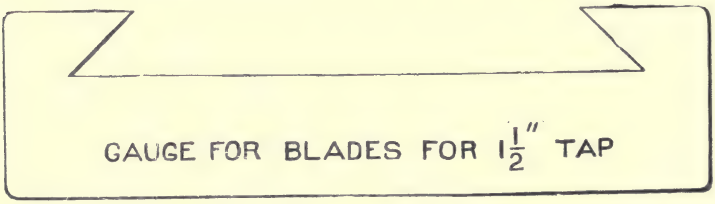


Fig. 99.

.005 inch smaller than the size the tap is to cut and the threads very carefully cut; after which the face of the blades may be milled as explained, the cutting end chamferred, and the necessary amount of clearance given the cutting edges by filing. The blades are now ready for hardening.

When hardening, the blades should be subjected to a slow heat in a muffler furnace, or a tube. When a blade reaches a low uniform red heat, it should be immersed in a bath of luke-warm water or brine, and worked up and down to insure uniform results. After hardening it may be brightened and drawn to a deep straw color. It is well to place all the blades in a pan having a long handle, as shown in Fig. 100. Coarse sand to a depth of about $1\frac{1}{2}$ inches may be placed in the bottom of the pan with the blades. The pan should be placed over a bright fire and shaken carefully so that the teeth will not be dulled by striking the other hardened blades, while the sand and the blades are heating. The motion causes it to heat uniformly and the sand keeps the surface of the work bright so that the temper colors may be readily seen. This method of drawing temper will be found very satisfactory on many classes of work. It is also used extensively when coloring pieces by heat where a great many pieces are to be colored uniformly.

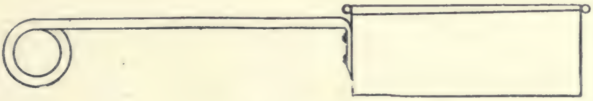


Fig. 100.

Square Thread Taps. Although the square thread is not as extensively used as formerly, having given place in many shops to the "Acme Standard," yet it is sometimes necessary to make taps for this form.

Steel should be selected sufficiently large and the decarbonized portion removed; the shank should be turned to size. The square should be milled for a wrench and the size and number of threads per inch stamped on the shank. The cutting end of the tap should be turned to size, the necessary amount of taper given the tap and then the threads cut

The tool used for cutting square threads is similar in form to a cutting-off (parting) tool except for its angle of side rake; it should be made of the proper thickness at the point but should be somewhat narrower back of the cutting end, as shown in Fig. 101, in order that it may clear when cutting.

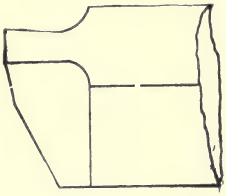


Fig. 101.

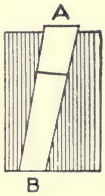


Fig. 102.

The thickness of the cutting end should be one half the distance from the edge of one thread to the corresponding edge of the next thread. For a square thread of 2 pitch, the land and space together would be $\frac{1}{2}$ inch, while the land and space would each be $\frac{1}{4}$ inch wide. The point of the tool would be $\frac{1}{4}$ inch thick.

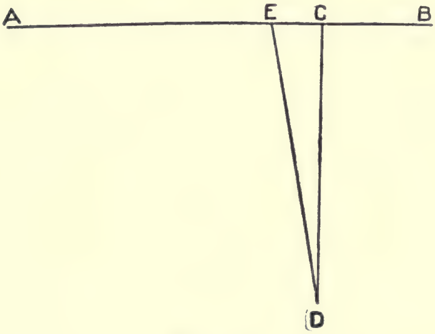


Fig. 103.

The sides of the tools from A to B, Fig. 102, must be inclined to the body as shown, the amount of the inclination depending upon the pitch of the thread and diameter of the tap to be cut. It may be determined, however, by the method shown in Fig. 103. Draw the line A B, and at right angles to it draw C D, whose length must be equal to the circumference of the thread to be cut, measured at the bottom or root of the thread. On A B lay off from the point C a distance E C equal to the pitch of the thread to be cut. Then draw the line D E, which will represent the angle of the side of the thread; the angle of the side of the cutting tool must be sufficiently greater to give the necessary clearance. It is advisable to cut the thread with a tool somewhat narrower than the required width at first, and finish with a tool of the proper thickness.

Square thread taps may be fluted according to directions given for V thread taps. If a tap is intended to cut a full thread, it must be well backed off, in order to avoid the necessity of using so much force that the tap would be broken. When a tap is to be used to size a hole whose thread has been cut by a smaller tap, very little clearance is necessary.

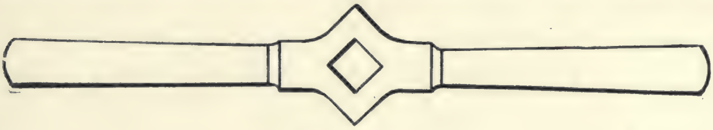


Fig. 104.

Tap Wrenches. When taps are used whose squares are all of a size, a solid tap wrench may be made, as shown in Fig. 104. This wrench is forged nearly to shape, the handles turned to size in the lathe, and the square hole in the center drilled and filed.

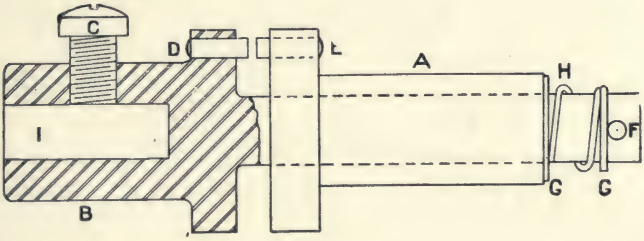
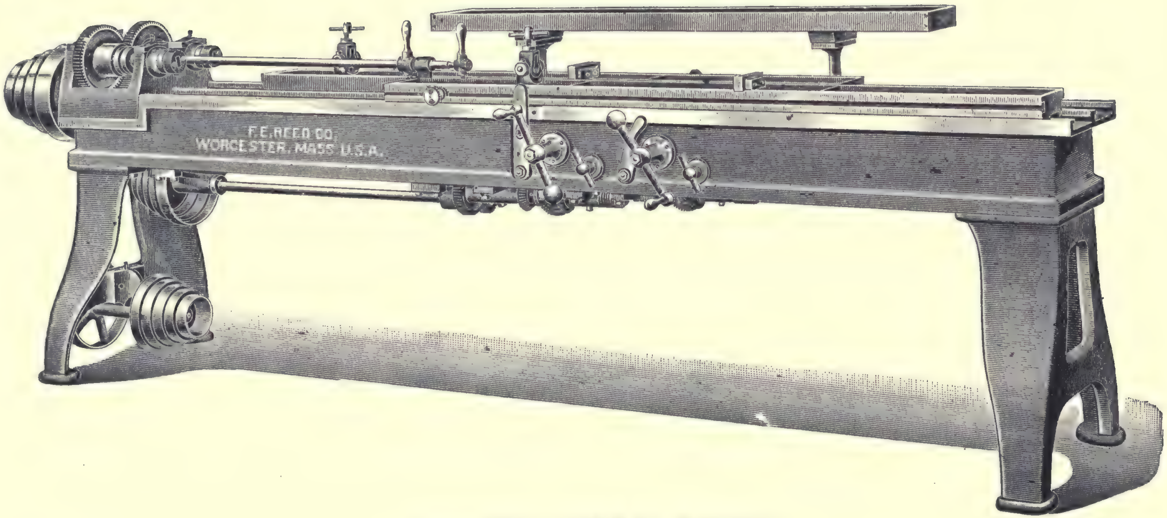


Fig. 105.

Releasing Tap Holders. When holes are to be tapped to a uniform depth in a screw machine or turret lathe, a tap holder is used which automatically releases the tap when it reaches the required depth. A very common form which gives excellent results when properly made and adjusted is shown in Fig. 105. It consists essentially of a sleeve A, which fits the tool holes in the turret of the screw machine, and the tap holder B, which fits the hole in the sleeve in such a manner as to slide longitudinally. The sleeve A should be made of tool steel if of a diameter that makes the wall around the hole thin; the hole should be drilled and reamed to size, and the outside turned to size. The portion of the sleeve which enters the hole in the turret should be a snug fit. The tap holder B should be made of tool steel, or of a grade of machinery steel possessing great stiffness and good wearing qualities. After roughing out to sizes somewhat larger than finish, the end which is to hold the tap may be turned to size and the (stem) end which is to run in the sleeve may be fitted, after which the hole I, to receive the tap may be made of a convenient size. In order that the hole may be perfectly concentric with the holder it will be necessary to run the large end of the holder in the steady rest of the lathe; the opposite end should be fastened against the head center of the lathe in such a manner that the stem runs perfectly true. With work of this nature, the head center of the lathe must be in good condition and run true.

After the hole has been drilled somewhat smaller than finish size, it is necessary to true the hole with a boring tool; the hole should be bored to within .010 inch of finish size, after which it may be reamed with a rose reamer. Before reaming, however, the outside edge of the hole should be chamferred to the shape of the point or cutting end of reamer, to avoid any possibility of the reamer running. Some tool makers never ream a hole of this nature if it can be avoided, always boring to size with a tool that makes a smooth cut; but if extreme care is used, results good enough for a tool of this character may be obtained if the holes are finished to size with a reamer.



GUN-BARREL REAMING MACHINE.

F. E. Reed Company.

TOOL MAKING.

PART II.

THREAD CUTTING DIES.

The size of a die is always denoted by the diameter of screw it will cut; a die that will cut a $\frac{1}{2}$ inch screw is called a $\frac{1}{2}$ inch die, irrespective of the outside diameter of the die itself.

Thread cutting dies are made solid or adjustable. Solid dies are used when extreme accuracy is not required. They are comparatively inexpensive, and may be used to advantage as a roughing die when an adjustable die is used for finishing. Owing to the tendency of dies to change their sizes when hardened, and to the fact that there is no provision for wear, they cannot be used where work must be made to gauge. They are extensively used in cutting threads on bolts, and for this class of work are made square, as shown in Fig. 106.

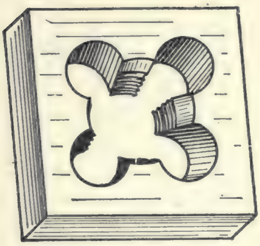


Fig. 106.

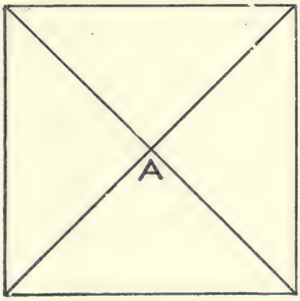


Fig. 107.

In making a square die the blank may be machined to thickness and to size on the square edges. One of the flat surfaces should be coated with blue vitriol, or the blank may be heated until it shows a distinct brown or blue color. The center may be found by scribing lines across corners, as shown in Fig. 107. It should be prick punched at A where the lines intersect. The die blank may be clamped to the face plate of a lathe and made to run true by means of the center indicator. If there is no tap of the proper size, and only one die is to be made, the thread may be cut with an inside threading tool, provided the hole is of sufficient size; if not, a tap must be made. If the thread is cut with a threading tool, the size must be determined by means of a male gauge, which may be a screw of the proper size. After threading, the hole should be chamferred to a depth of three to four threads, the amount depending on the pitch of the thread; a fine pitch not requiring as many threads chamferred as a coarse pitch. The chamferring should not be much larger on the face of the die than the diameter of the screw to be cut. Figs. 108 and 109 show two views of a die chamferred and relieved on the cutting edges. The chamferring may be done with a countersink or taper reamer of the proper angle. In the absence of such a cutter, a tool held in the tool post of the lathe may be used.

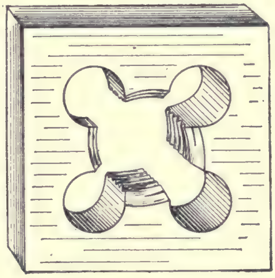


Fig. 108.

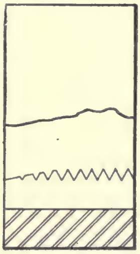


Fig. 109.

Most manufacturers making dies for the market give four cutting edges to all sizes up to and including four inches. When dies are made in the shop where they are to be used, custom varies. Some tool makers advocate three cutting edges for all dies smaller than $\frac{1}{4}$ inch, and five or more cutting edges for dies above two inches. The objection to more cutting edges than are absolutely needed on large dies is the increase in the cost of making.

When making dies for threading tubing, or for work where part of the circumference is cut away, it is better to give them a greater number of cutting edges than would otherwise be the case.

Rake of Cutting Edges. For general shop work, where the dies are to be used for all kinds of stock, it is advisable to make the cutting edges radial as shown in Fig. 110, the cutting edges

A A A A all pointing to the center. For cutting brass castings, the cutting edges should have a slight negative rake as shown in Fig. 111, the cutting edges A A A A all pointing back of the center.

Clearance Holes. After threading and countersinking (chamferring), screw in a piece of steel threaded to fit the die, and face it off flush. Lay out the centers of the clearance holes on the back of the die, and drill with a small drill the size of the pilot of a counterbore whose body will cut the right size for the clearance hole. The centers of these holes for dies having four cutting edges, and from $\frac{3}{8}$ to $\frac{3}{4}$ inch may be the intersections of a circle having a diameter equal to the diameter of the screw to be cut, and lines drawn across the corners as shown in Fig. 112. Prick punch these points. For a die having four clearance holes whose centers are laid out as shown in Fig. 112, it is customary to make the clearance holes one half the size of the die; that is the size of clearance holes in a $\frac{1}{2}$ inch die would be $\frac{1}{4}$ inch. The width A, Fig. 113, of the top of the lands should be about $\frac{1}{16}$ of the circumference of the screw to be cut. The diameter of clearance holes given does not apply to dies smaller or larger than sizes given ($\frac{3}{8}$ to $\frac{3}{4}$ inch), especially if the dies are to be used in the screw machine, as the clearance hole not only

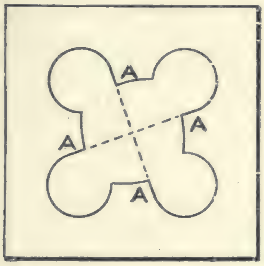


Fig. 110.

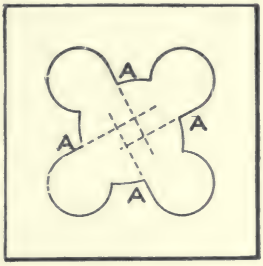


Fig. 111.

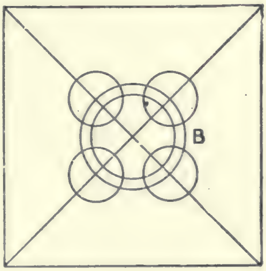


Fig. 112.

provides a cutting edge, but also makes a convenient place for the chips; if these are so small that the oil cannot wash the chips out, the chips clog the holes and tear the thread.

For small dies the clearance holes are of a size that allows the chips to collect in the holes without tearing the threads, and are located a greater distance from the center of the die, in order to give sufficient strength to the lands. The desired shape and thickness may be given the sides of the lands by filing. When it is considered advisable to give screw dies above $\frac{3}{4}$ inch larger clearance holes than the size mentioned, they may be located at a distance from the center of the die that will give the desired thickness to the land.

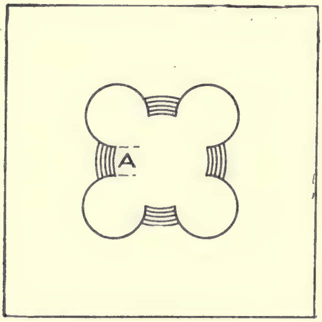


Fig. 113.

For screw machine and turret lathe work, dies are generally made circular, and as holders for dies are part of the equipment of every shop having screw machines, the dies should be made to fit these holders; but it is not considered good practice to make the diameter of dies less than $2\frac{1}{2}$ times the diameter of the screw to be cut, and the thickness of the die may be $1\frac{1}{4}$ times the diameter of the screw.

ADJUSTABLE DIES.

While round dies for screw machine work may be made solid for roughing out a thread that is to be finished by another die, the finish die should be made adjustable in order that the desired size may be obtained. When making adjustable dies the same general instructions may be followed that are given for making solid dies, except that some provision must be made for adjustment. This is done by splitting the dies at one side as shown at A in Fig. 114. In order that the die may not spring out of shape in hardening, it is advisable to cut the slot from the center of the die, leaving a thin margin as shown at A, Fig. 115; after the die is hardened this may be cut away with a beveled emery wheel. If the thickness at B is too great to allow the die to close readily when adjusted to size, the hole shown may be drilled and connected with the clearance hole by means of a saw cut.

If many round dies of the same diameter are to be made it is economical to have a holder with a shank which fits the hole in the spindle of the lathe; the opposite end should be made to receive the die blanks which should be turned to fit the die holder in the screw machine. Fig. 116 shows the holder to be used in the lathe. A represents a die blank in the holder; B is the shank which fits in the spindle of the lathe; C is a recess in the holder to provide for the projection left on the blank when it is cut from the bar and also provide an opening to receive the drill and tap after they run through the die. After the blank is placed in the holder and secured in position by the screw D, the outer surface may be faced smooth and true with the circumference, after which it may be reversed and the opposite side finished to the proper thickness. The die may now be drilled and tapped. Be-

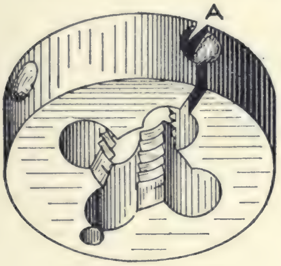


Fig. 114.

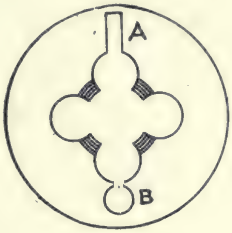


Fig. 115.

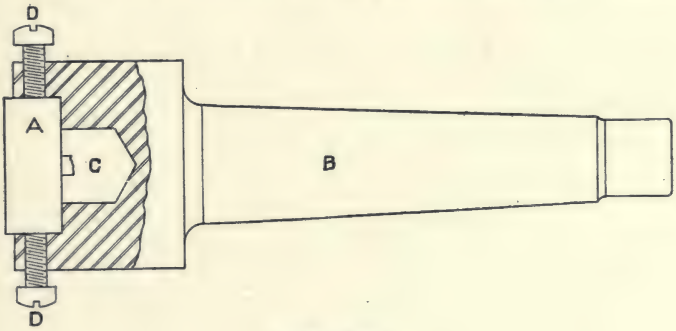


Fig. 116.

fore drilling, the die should be carefully centered in the lathe; to insure a full thread in the die, a drill a few thousandths of an inch smaller than tap size should be used in drilling, after which a reamer of the proper size may be run through. When tapping the thread, it is advisable to use two or three taps of different sizes; the finish tap should be the size of the desired hole in the die, and should be of the form known as screw die hob. Where several taps are used in tapping a die, there should be some difference in the diameter so that any inequality in the shape or pitch of the thread may be removed by the larger tap, otherwise imperfect threads will result. For instance if three taps are to be used for a ¼ inch die, the first tap may be .230 inch diameter; the second .240 inch diameter, and the finish tap .250 inch diameter if the die is to be solid. If it is to be an adjustable die, the finish tap should be .253 inch diameter in order to furnish clearance to the lands when it is closed to .250 inch.

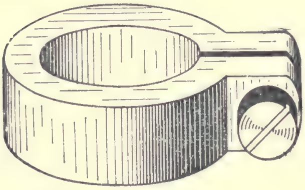


Fig. 117.

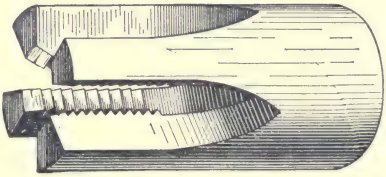


Fig. 118.

Dies should be heated very slowly for hardening, either in a muffler furnace, or in some receptacle to protect it from the action of the fire. When the die is heated to a uniform low red it may be immersed in a bath of lukewarm brine and worked back and forth to insure hardening the threads. The temper should be drawn to a full straw color. If it is an adjustable die the portion marked B, Fig. 115, should be drawn to a blue color in order that it may spring without breaking; this may be done by placing this portion of the die on a red hot iron plate, or the jaws of a heavy pair of tongs may be heated red hot, the die may be grasped in the tongs and held until the desired color appears. Do not allow the blue color to extend to the threads or they will be too soft. When the desired color has been obtained the die may be dropped into oil to prevent drawing the temper more than is desired.

Spring Screw-threading Dies. This form of die is adjusted by means of the clamp collar shown in Fig. 117; the die is shown in Fig. 118. In some shops it is the only form of screw-threading die used for screw machine work. When so used it should be fitted to one of the holders on hand, provided there be one of the proper size.

Average proportions of spring dies are given in the following table; these sizes are used by a manufacturing concern using a great many screw-threading dies of this description. It is not necessary to follow the proportions given, as they are intended only as a guide, and may be changed to suit circumstances. All dimensions are in inches.

SPRING SCREW-THREADING DIES.

Size of Screw.	Outside Diameter.	Length.
$\frac{1}{8}$ to $\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$
$\frac{1}{4}$ to $\frac{3}{8}$	$\frac{3}{4}$	$1\frac{3}{4}$
$\frac{3}{8}$ to $\frac{1}{2}$	1	2
$\frac{1}{2}$ to $\frac{3}{4}$	$1\frac{1}{4}$	$2\frac{1}{4}$
$\frac{3}{4}$ to 1	$1\frac{5}{8}$	$2\frac{1}{2}$
1 to $1\frac{1}{4}$	2	3
$1\frac{1}{4}$ to $1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{2}$
$1\frac{1}{2}$ to 2	$3\frac{1}{4}$	4

For uniform and well-finished threads, two dies should be used, one for roughing, and one for finishing.

Where many dies of a size are made it is best to have a holder with a shank fitting the center hole of some lathe. The stock can be machined to size and cut to length. The clearance hole in the back of the die should be first drilled somewhat larger than the diameter of the screw to be cut. For dies up to and including $\frac{1}{8}$ inch the clearance holes should be $\frac{1}{32}$ inch large; for dies $\frac{1}{8}$ to $\frac{1}{4}$ inch it should be $\frac{3}{64}$ inch large; for dies $\frac{1}{2}$ inch and over, it should be from $\frac{1}{16}$ to $\frac{1}{8}$ inch large. After drilling the clearance hole, the die should be reversed in the holder, and drilled and tapped the same as a round die, using a hob to finish the threads to size. For general work, the die should have four cutting edges making the lands about one-sixteenth the circumference of the screw to be cut. Chamfer about three threads. The length of the threaded portion of the die should not exceed one and one-quarter times the diameter of the screw to be cut. To produce the cutting edges, use a 45° double angle milling cutter shown in Fig. 119; this cutter should be of sufficiently large diameter to produce a cut as shown in Fig. 120.

The chamferred edges should be relieved and the cutting edges finished with a fine file. Stamp the size and number of threads on the back end of the die as shown in Fig. 120 and then harden. The die should be heated in a tube and hardened in a jet of water coming up from the bottom of a tank in order that the water may enter the threaded portion. It should be hardened a little farther up than the length of the thread, moving up and down in the bath to prevent a water line; the temper should be drawn to a full straw color.

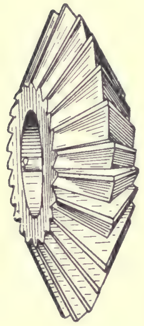


Fig. 119.

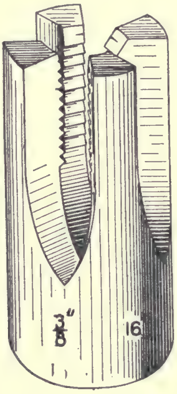


Fig. 120.

Where many clamp collars are used, castings of malleable iron or gun metal may be made from a pattern; the hole should be cored to within $\frac{1}{16}$ inch of finish size. The hole may then be drilled and reamed. When the screw hole has been drilled and tapped and the collar split, it is ready to use. If the surfaces are finished it adds very materially to the cost.

Die Holders. When cutting threads in screw machines and turret lathes, dies are held in die holders which are constructed in two parts as shown in Fig. 121. The shank A fits the hole in the turret, while the die holder B has a stem that fits the hole in the shank. While the die is cutting, the pins D and C are engaged, thus preventing the holder B from turning. When the turret slide of the screw machine has traveled to its limit, the holder is drawn out of the shank until the machine is reversed when the pins engage on their opposite sides. A pin is put through the stem of the holder at E; this strikes the end of shank just at the time the pins D and C become disengaged.

Both shank and body may be made of machinery steel; the shank may be finished to size except the portion marked A, which should be left .010 inch large for grinding. The front end of the hole should be rounded as shown in Fig. 121, to allow the fillet in the shoulder of the stem to enter. This fillet is left for strength. The pin hole should be drilled and reamed. When the holders are to take dies not over $\frac{1}{8}$ inch in size, this pin hole may be $\frac{3}{16}$ inch diameter; from $\frac{1}{8}$ to $\frac{5}{16}$ in size, $\frac{1}{4}$ inch diameter. As the dies increase in size the pin must increase proportionately. The shank may be case-hardened in a mixture of granulated charred leather and charcoal; it should run about two hours and then be dipped in a bath of oil. The hole should be lapped straight and true. The outside ground to fit the hole in the turret. The pin C should be of tool steel hardened and drawn to a blue color, and forced into place.

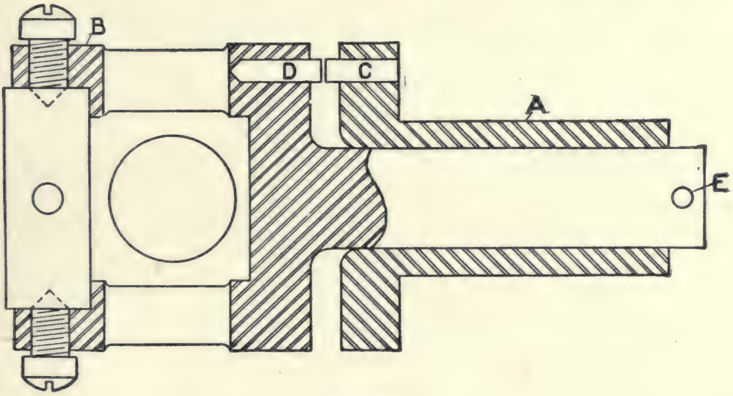


Fig. 121.

The holder B may be made from a forging, or turned from a solid piece. After roughing to size somewhat larger than finish, the stem may be turned and fitted to the hole in the shank; it should turn *freely* in the shank. The larger portion (or body) should now be turned to size. This should be run in the steady rest, and the end drilled and bored for the die and for clearance back of the die as shown in Fig. 121. Three or four large holes should be drilled into the clearance hole in order that the chips and oil may find a way of escape, thus preventing injury to the threads of a screw long enough to reach through the die when being threaded.

Screw holes should be drilled and tapped as shown in Fig. 121; the screws are to hold the die in position in the holder and also to adjust to size dies that are split. The stem may be placed in the shank and the pin hole transferred through the pin hole in the shank into the body; this should be done before the pin C is pressed into place. The pin D should be hardened the same as C.

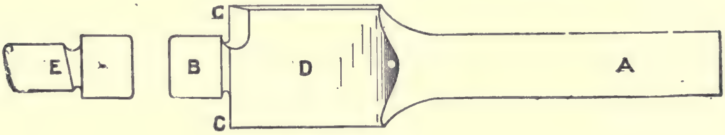


Fig. 122.

The pin hole for the pin E may be drilled in a location that allows C and D to become disengaged and yet have no play between the two

COUNTERBORES.

Counterbores are used for enlarging a hole without changing its relative position. For a *hurry up* job and for a small number of holes, it is advisable to make as cheap a form as is consistent with the work to be done. Probably the cheapest counterbore that will do satisfactory work is the flat form shown in Fig. 122. This can be forged to require but little machine work. After forging, turn to size; finish the shank A and pilot B with a fine file before taking from the lathe. The cutting edges C C should be faced true and smooth. The necking between the pilot and the body should be cut with a tool having the corners slightly rounded to decrease the liability of cracking when the counterbore is hardened. The flat sides D of the body may be finish filed; the edges should be draw-filed, removing more stock on the back than on the cutting edge to prevent binding. File the cutting edges C C for clearance, as shown at E, Fig. 122. The pilot and the body should be hard the entire length or they will wear and rough up and consequently cannot cut a smooth hole; draw the temper to a full straw color. Unless intended for *accurate* work it need not be ground.

For permanent equipment, counterbores are usually made with four cutting edges as shown in Fig. 123 and Fig. 124. Fig. 123 representing a taper shank counterbore for a taper collect, while Fig. 124 has a straight shank to be used in a chuck, or collet having a straight hole the size of the shank.

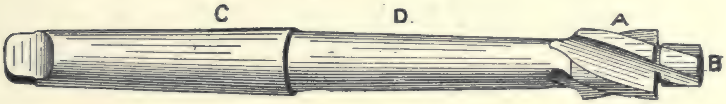


Fig. 123.

Counterbores for screw holes are usually made in sets of three, one for the head of the screw with pilot (or guide) of body size, one for head with pilot of tap drill size, and one to enlarge a tap drill hole to body size. The following instructions apply to counterbores with either straight or taper shanks. Take stock somewhat larger than finish size of counterbore.

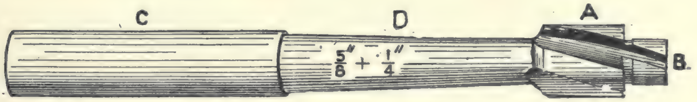


Fig. 124.

Turn a roughing chip all over the piece; turn the necked portion between the shank and body to size and stamp size of counterbore and pilot as shown in Fig. 124; turn shank C, body A, and pilot B .015 to .020 inch above finish sizes, to allow for grinding. In the case of the taper shank counterbore shown in Fig. 123 the tennon should be milled. The counterbore is now ready to have the grooves milled to form the cutting edges. One method is to cut them with a right-hand spiral of from 10° to 15°; the other method is to cut the grooves straight. The former has he effect of running chips back from the cutting edges and works very well on wrought iron and steel, while the latter method is considered more satisfactory for brass and cast iron and also works well on wrought iron and steel. The cutting edges are given clearance by filing, as shown at A in Fig. 125. If the counterbore is to be used for brass it is necessary to give clearance to the lands also as shown at A A A A, Fig. 126.

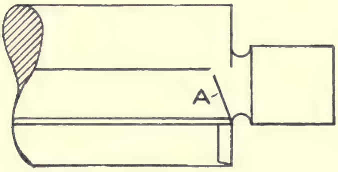


Fig. 125.

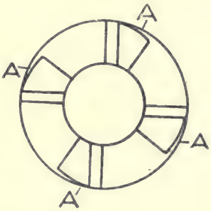


Fig. 126.

When centering counterbores or any tools whose centers are not to be used after the tool is finished, the drill should be small and the countersinking no larger than is necessary for good results in machining. If large centers should, by accident, be put in the ends, the one on the end to be hardened should be filled with fire clay moistened with water to the consistency of dough, or with graphite mixed with oil; this prevents steam forming in the

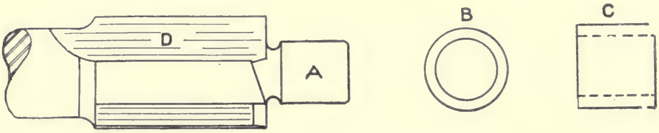


Fig. 127.

hole and cracking the tool when dipped in the bath. If the piece is to be heated in lead, the filling should be dried thoroughly before immersing in the red-hot lead.

Solid counterbores can be used with holes larger than the pilot by forcing a sleeve over it as shown in Fig. 127. B and C are two views of the sleeve which is to be forced on to pilot A. After hardening, the counterbore may be ground to size on the shank, body and pilot; the shank should be ground first as the length is greater, and in the case of a counterbore having a straight shank the grinder may be adjusted to perfect alignment by measurement.

Two lipped counterbores are sharpened by grinding on the flat faces marked D, Fig. 122. Grind a four-lipped counterbore on the flat side of the groove as D in Fig. 127.

Facing Tool with Inserted Cutter. Where a limited number of holes are to be counterbored, the tool shown in Fig. 128 may be made. All that is necessary in making this tool is a piece of stock A, the size of the hole to be counterbored and a piece of drill rod for the cutter B; this may be filed to a cutting edge, hardened and driven in place. If accuracy is essential, a piece of drill rod must be cut off somewhat longer than the diameter of the required hole; it should be driven into the hole in the bar leaving an equal length on each side. It may be turned to the correct diameter and filed to shape. If several cutters are to be used in the same bar, or if the tool is to be used as a facing bar, to square a shoulder inside a piece of work as shown in Fig. 129, the cutter B is removed from the bar and after the bar is in place it is inserted and held by set screw C.

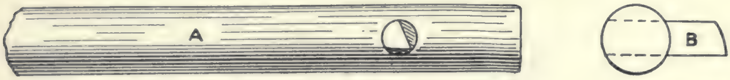


Fig. 128.

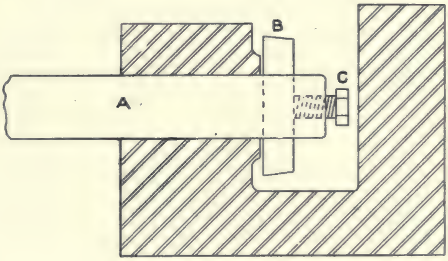


Fig. 129.

For large work, a counterbore may be made as shown in Fig. 130, A being the cutter bar which should be made of tool steel $\frac{1}{16}$ to $\frac{1}{8}$ inch larger than finish size. After taking a roughing chip, leaving it a trifle large, the slot should be made to receive the cutter C. This is done by drilling a series of holes as shown in Fig. 131. After prick punching the bar, it should be clamped to a drill press table, holding the bar in a pair of V blocks. The prick punch marks should be set in a position that will insure the drill holes going through the center of the bar; this can be done as follows: place the square against one side of the bar, measure to the center, then place the square against the opposite side and measure in the same manner. When the distance is the same on each side from the square blade to the centers, the piece is in the proper position for drilling. The drill press table may then be swung around until the prick punch marks are in proper location with the spindle of the press. After drilling, a drift may be driven through to break the walls separating the holes and the slot filed to size. The bar should be placed with one end in the steady rest and the other end strapped to the head center of the lathe. The screw hole in the end is now drilled and tapped into the slot in order that the screw may bind the cutter. The end should be countersunk to provide a center for finish turning. The bar may be turned to size at A and the pilot finished to size. The screw D should have a head $\frac{1}{16}$ inch larger than the part B in order that it may hold the sleeve in place, should it have a tendency to come off when removing the counterbore from the hole. The cutter C should be a close fit in the slot. A headless screw should be made short, so that it will not interfere with the dead center of the lathe when it is screwed to place against the

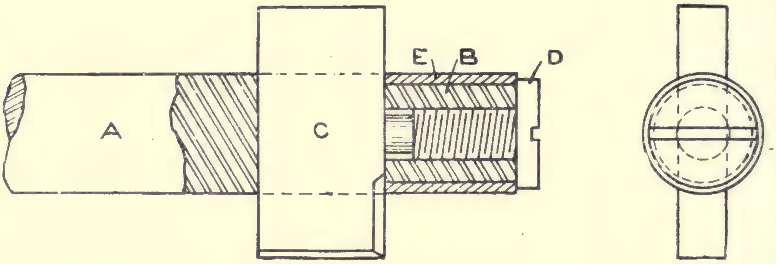


Fig. 130.

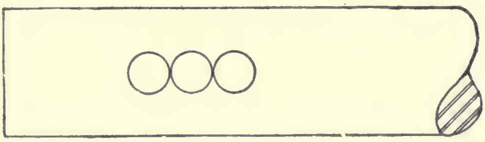
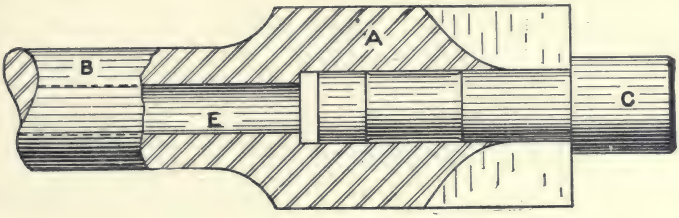


Fig. 131.

cutter blank. It is intended to be used when turning the cutter to the right diameter, and should be kept for that purpose.

Counterbores with Inserted Pilots are useful when the counterbores need frequent sharpening, or when a variety of different sized holes are to be counterbored to the same size. A common form of counterbore having an inserted pilot is shown in Fig. 132.



Fig, 132.

When making this counterbore the stock should have a roughing chip taken off and the hole E drilled part way from the shank end. This drilling may be done in the speed lathe, holding the drill in a chuck in the head spindle ; the center in the opposite end of the piece should be on the dead center of the lathe. If the piece is turned one-half revolution occasionally the drill will cut accurately enough, as perfect alignment is not necessary in this hole, since it is intended only for use when driving out the pilot.

After drilling, the shank end should be carefully countersunk. The piece may now be turned to grinding size which should be from .015 to .020 inch all over. After turning the outside, the hole for the pilot may be drilled and bored, running the large end of the counterbore in the steady rest. The counterbore should have four cutting edges for all ordinary work ; these may be cut with a side milling cutter with a face sufficiently wide to cover the width of tooth. The form of cutter is shown in Fig. 133, while an end view of the teeth is shown in Fig. 134. When mil-

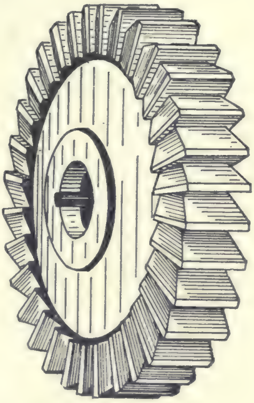


Fig. 133.

ling the teeth, the counterbore can best be held in the chuck on the spiral head. If a more stubbed form of tooth is needed than the one shown in Fig. 132, the spiral head may be tipped to the desired angle and the cutter fed through instead of sunk into the counterbore. After milling, the burrs should be removed, the counterbore stamped and hardened. While hardening, it should be heated to a red nearly the whole length of body; when dipped in the bath it should be inverted in order that the teeth may be uppermost, it should then be worked up and down rapidly in the bath until the red has entirely disappeared. It should be allowed to remain in the bath until cold. If larger than 1 inch diameter the *strain* should be removed immediately upon taking from the bath by heating over the fire as already explained. The pilot should be turned as shown in Fig. 135. A and BB should be left about .010 inch large for grinding after hardening; C should be turned $\frac{1}{32}$ inch smaller than the hole in the mill, as this does not bear when the pilot is in place. A slight depression should be made between the head and the first bearing point B for the emery wheel to pass over when grinding. When hardening, A is the only part that needs to be hard, but, unless a piece of tube is slipped over the stem B when the pilot is put in the bath it will be almost impossible to harden A the entire length and leave B soft. As A is likely to rough up when used it is best to harden a short distance on the stem B, unless there should be a great difference in size between A and B; in which case a tube, or a piece of iron with a hole drilled in the end the size of B and having the end beveled as shown in Fig. 136, should be slipped over B when the pilot is heated. This cover should be slipped over the stem and up against the shoulder of the head to prevent a *water line*;

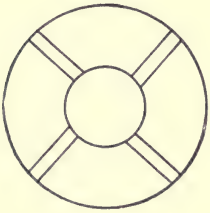


Fig. 134.

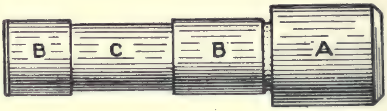
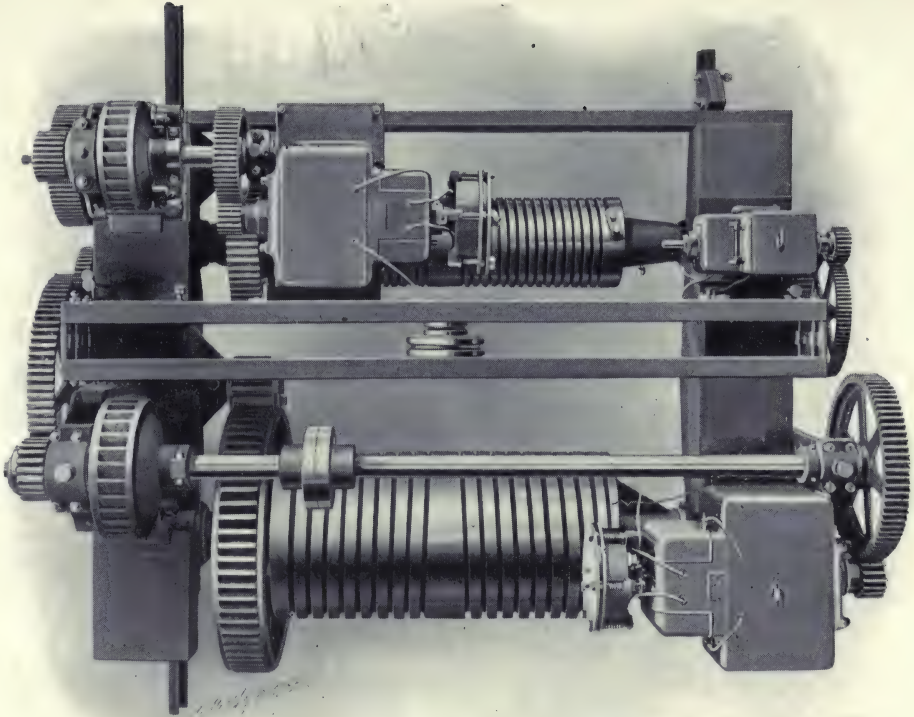


Fig. 135.



TROLLEY OF 15 TONS CAPACITY.

The Case M'f'g Co.

if this precaution is taken there is no danger of pilot cracking under the head. After hardening and tempering, the pilot may be ground to size at A, and the portions B B ground to fit the hole of the counterbore. After grinding, the pilot may be forced into place. The counterbore may be ground with the pilot in position. When dull the pilot should be forced out of the counterbore and the cutting edges ground with an emery wheel.

Fig. 136.

Combination Counterbores are made when it is necessary to change the size of counterbore and pilot frequently. A shank or bar is made to accommodate different sizes of cutters, and sleeves serve as pilots. In Fig. 137, A is the cutter, B the pilot which is tapped in the end to receive a screw which holds the sleeves, and C the shank which is held in a chuck or collet, when the counterbore is in use.

After taking a roughing chip off the bar, the end B is run in the steady rest and the hole for the screw F is drilled and tapped. The outside end is countersunk to a 60° angle to run on a center. When machining the holder, the portions B, C, and D should be left about .010 inch larger than finish size to allow for grinding. But if no grinder is at hand it may be left a few thousandths of an inch above size, and filed to finish dimensions.

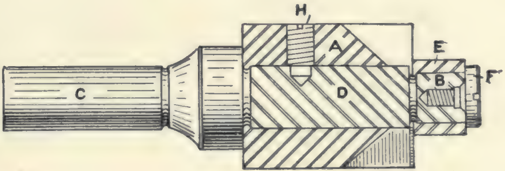


Fig. 137.

The body (or cutter) A, should have a hole $\frac{1}{16}$ inch smaller than finish size drilled through it; the outside surface should be turned off, and the piece annealed. If a grinder having an internal grinding attachment is at hand, the hole in the cutter should be left .005 inch small for grinding. If such an attachment is not at hand the hole may be reamed to finish size. The outside diameter should be left about .010 large; the ends should be faced to length, and the teeth cut. If four teeth are to be cut, the work may be done with a side milling cutter as shown in Fig. 133. The counterbore should be held in a chuck on the spiral head spindle, which should be tipped to produce a strong tooth as shown in Fig. 137. Before hardening, the hole should be drilled and tapped for the screw H which holds the counterbore to the bar. To harden, the counterbore should be given an even, low red heat, and plunged in water or brine in such a manner that the bath will come in contact with the teeth. If the teeth are stubbed and strong the temper need not be drawn more than to a light straw color.

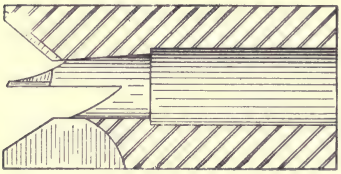


Fig. 138.

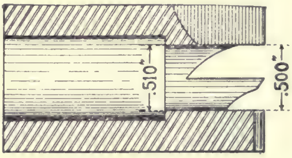


Fig. 140.

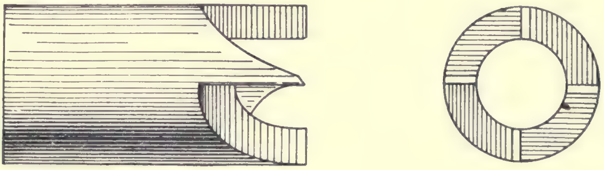
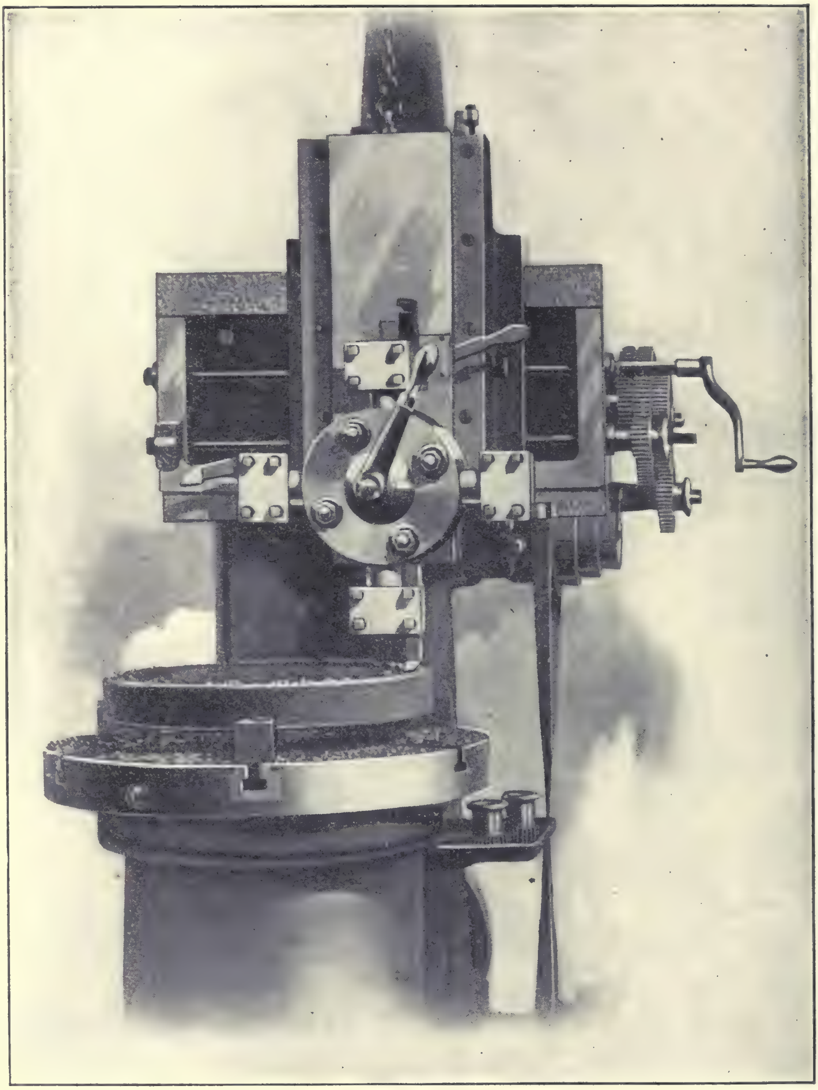


Fig. 139.

The screw H should be made of tool steel having a projection $\frac{1}{8}$ inch long on one end, turned to the bottom of the thread; this is to enter a hole drilled in the bar or holder, and keep the counterbore from turning. The end of the screw should be about .005 inch smaller than the hole. The screw should be hardened and drawn to a blue color. The sleeve intended to go on the pilot E should be made of tool steel, hardened and ground to size inside and out. The screw F may be made of machinery steel,



BORING AND TURNING MILL.

Facing and Boring Chuck Gear Ring.

Bullard Machine Tool Co.

and case-hardened sufficiently deep by heating to a red and sprinkling with powdered cyanide of potassium, after which it is reheated and plunged in water.

HOLLOW MILLS.

Hollow mills are used in screw machines and turret lathes for roughing down and finishing. They are also used in drill press work in finishing a projection which must be in some given position ; when thus used they are generally guided by a bushing in a fixture, to bring the projection in the proper location.

For roughing out work on a screw machine or turret lathe, solid mills having strong stubbed teeth are preferred for rigidity. For finishing they are made adjustable in order to get *exact* sizes. Fig. 138 shows a solid hollow mill having the cutting end hollowed out in the form of a V, in order that it may center itself when starting to cut. Fig. 139 shows a form of solid hollow mill intended for use in squaring up a shoulder at the end of a cut that has been made with a mill of the form shown in Fig. 138, or it may be used for roughing out a piece; however, it will not center itself as readily as the one shown in Fig. 138.

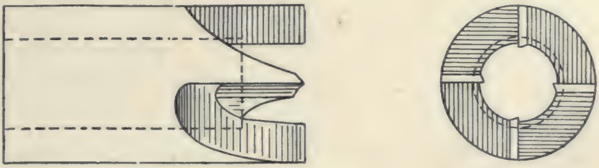


Fig. 141.

For small hollow mills some tool makers advocate three cutting teeth, while others claim better results with four teeth on all sizes.

The rear of the mill is bored somewhat larger than the cutting end, to allow it to clear on long cuts. The cutting end must be relieved or it will bind and rough the work, and probably twist it off in the mill. There are several methods of relieving mills ; the more common one is to ream the hole tapering, making it larger at the back end, as shown in Fig. 140. Another method is to file back of the edges, as shown in Fig. 141.

For making hollow mills having the same outside diameter, it is advisable to use a holder of the form shown in Fig. 142, having a taper shank which fits the spindle of a lathe. The hole in the other end of the holder should be the size of the holder in the screw machine or turret lathe, which holds the mills when in use. The steel for the hollow mills should be cut to length and turned to the proper diameter to fit the holder. After putting the blank in the holder, the ends may be squared and the holes drilled and bored to the desired sizes. If the mill is to be of the form shown in Figs. 138, 139 and 140, the cutting end may be reamed with a taper reamer to give the necessary clearance. The reamer should be run in from the back end in order that this end of the hole be larger. For the form shown in Fig. 141, the hole at the cutting end should be straight and to finish size.

The mill is now ready for cutting the teeth. If four cutting edges are to be given, a side milling cutter may be used of a diameter about double the diameter of the hollow mill to be cut. The blank should be held in a chuck on the end of the spindle in the spiral head. For a strong tooth, the spiral head may be set at an angle that will produce a tooth as shown in Fig. 143, by feeding the milling cutter *through* the blank. If a deeper tooth is desired, the spiral head may be set so that the blank will be in a vertical position, and the milling cutter fed in until the desired form and depth of tooth is obtained.

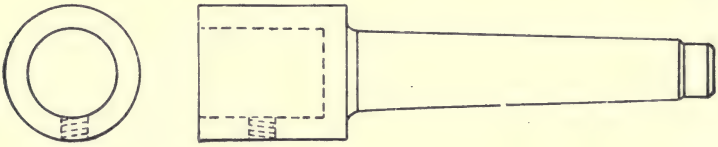


Fig. 142.

An Adjustable Hollow Mill may be made by following the instructions given for *solid* hollow mills, except that the mill must be split as shown in Fig. 144, in order that the size of hole in the mill may be altered. There are two methods of adjusting the mill: the outside of the cutting end of the mill is tapered, and a collar having a corresponding taper hole is forced on the mill. The collar closes it, and causes it to cut smaller. The other method is to turn the outside of the hollow mill straight, and close by means of the clamp collar shown in Fig. 145. As adjustable hollow mills are generally used for finishing cuts, and are not used when taking heavy cuts, the teeth may be made finer than those of solid mills used for roughing. The teeth being nearer together will finish a cylindrical piece more accurately than if the teeth were cut farther apart. It is customary to give adjustable hollow mills to be used for finishing from six to eight teeth. The cutting edges should be cut radial for most work. Better results will be obtained if the hole in the cutting end of the mill is left .005 inch small, and ground to size after the mill is hardened.

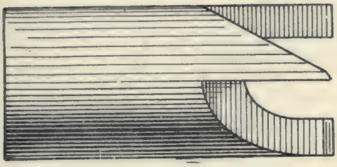


Fig. 143.

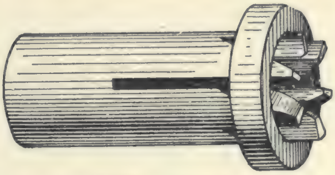


Fig. 144.

The hollow mill, whether it be solid or adjustable, should be hardened a trifle farther up than the length of the teeth, and drawn to a straw color. The mill is sharpened by grinding on the ends of the teeth.

Hollow Mill with Inserted Blades. For large work, hollow mills are made having inserted blades. The hollow mill with removable blades, shown in Fig. 146, does good service on rough work; the blades may be made of self hardening steel and inserted in a machine steel body. The grooves in the body to receive the blades should be milled with a cutter whose thickness corresponds to the size of the steel to be used for the blades. The grooves are cut somewhat deeper at the front end of the holder in order that the blades may have clearance to prevent binding. The edge of the slot corresponding to the cutting edge of the blade should be radial.

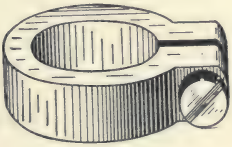


Fig. 145.

Two collars should be made of machinery steel having holes sufficiently large to allow their being placed on the mill when the blades are in the slots. Each collar should be provided with the same number of set screws as there are blades in the mill. One collar holds the blades in the holder, while the other is placed nearly at the ends of the blades to support them while cutting. This form of mill is used on cuts not exceeding one inch in length, as the blades must project beyond the holder to the desired length of the cut.

The size of cut may be changed somewhat by setting the cutters back or ahead in the slots, or paper may be placed in the slots under the blades to increase the diameter of the cut. The blades are set to an even length by bringing them against a surface perpendicular to the axis of the body of the tool.

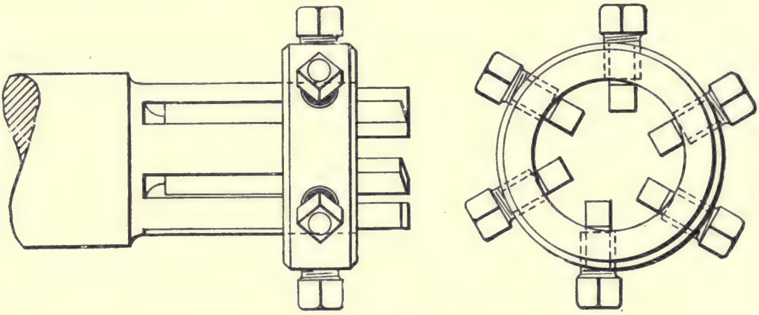


Fig. 146.

Hollow Mill with Pilot. It is often desirable to mill the outside of a projection central with a hole passing through it. This may be done very satisfactorily with a hollow mill having a pilot as shown in Fig. 147. It is advisable to hold the pilot in place by means of a set screw. In order to give clearance to the teeth to prevent the mill binding when cutting, the hole may be bored tapering .010 inch in $\frac{1}{2}$ inch of length, making it largest at the back end.

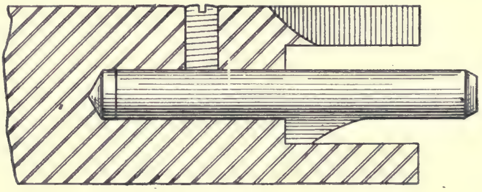


Fig. 147.

When hardening a mill of this description it is advisable to dip it in the bath with the cutting end *uppermost* working it up and down rapidly. After hardening, it may be drawn to a straw color. The pilot should be turned .010 inch above finish size, hardened, and drawn to a brown color, and ground to the desired dimensions.

FORMING TOOLS.

Forming tools are used when several pieces are to be made of exactly the same shape. They are particularly valuable for giving the desired shape to formed mills and similar tools and are extensively used in duplicating a given shape on work produced in the screw machine.

Forming tools are made flat and circular in shape. When used in the lathe for shaping milling machine cutters and similar tools they are generally made flat; for backing off formed milling machine cutters they are always made flat; for screw machines in duplicating a given shape they are made both flat and circular.

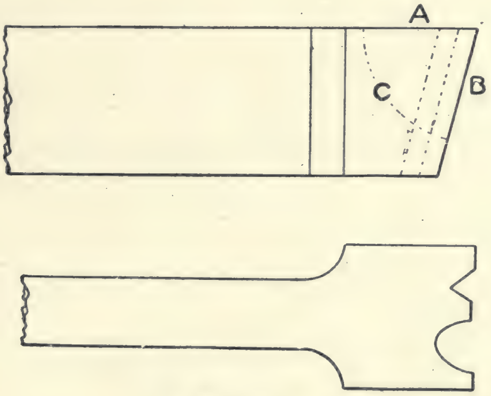


Fig. 148.

The flat forming tool is made as a solid cutter, the tool and shank being in one piece as shown in Fig. 148, or the cutter and shank may be made separate as shown in Fig. 149. When but one forming tool is to be made, that shown in Fig. 148 will be found to be inexpensive; but for making many tools, it will be found much cheaper to adopt the plan shown in Fig. 149.

On certain classes of work it is advisable to use a forming tool on a holder of the description shown in Fig. 150, which is known as a spring holder. On account of its design it may spring somewhat when used on heavy cuts, thus reducing the tendency to chatter. It is necessary to make these holders of tool steel, giving them a spring temper at point marked A. The slot

B allows the forming blade D to spring away from the work when under heavy strain. The blades may be planed up in long strips and cut off the required length. The tongue E should fit the slot O, which, with two cap screws through F and G, securely holds the blade in position.

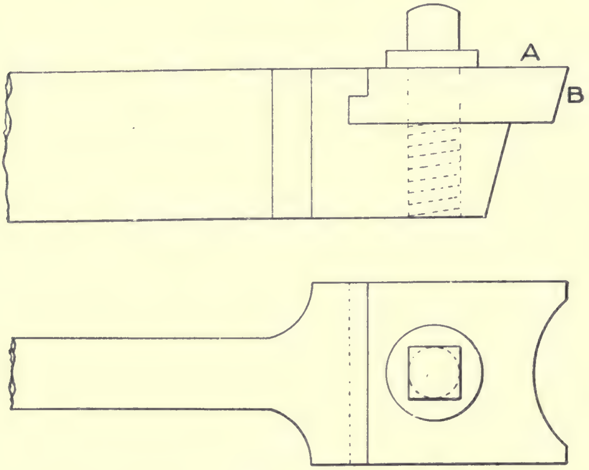


Fig. 149.

In order that a forming tool may cut readily, it is necessary to give the surface marked B a sufficient amount of clearance.

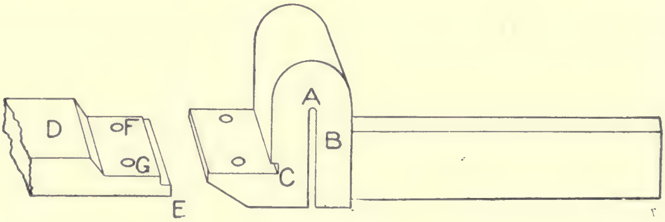


Fig. 150.

For tools to be used for shaping milling machine cutters and similar tools, a clearance of 10° to 15° will be ample; that is, the angle should be from 80° to 75°. But if the tool is to be used for backing off the teeth of formed milling machine cutters, it is necessary to give a clearance of 18° to 22°. When making a forming tool having the required angle at D, the shape can be produced by tipping the blank to the required angle and planing or milling with a tool having exactly the shape it is desired to produce. The tool used may be made of a shape enough different from that desired that it may produce the proper shape when the cutter is in a vertical position, and the blank at a given angle from that position as shown in Fig. 151. Or, the tool may be held in the tool post (or in a fixture made for the purpose) of the shaper or planer at the same angle as the blank being cut, as shown in Fig. 152, and it will produce a shape corresponding very closely with its own.

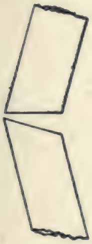


Fig. 151.

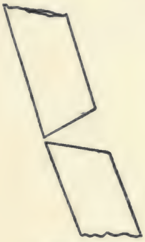


Fig. 152.

For screw machine and similar work for duplicating given shapes, a forming tool is made of the shape shown in Fig. 153. A represents a holder used by the Brown & Sharpe Mfg. Co. for use on their screw machines. B shows the forming tool blank. The desired shape is cut in the surface marked C.

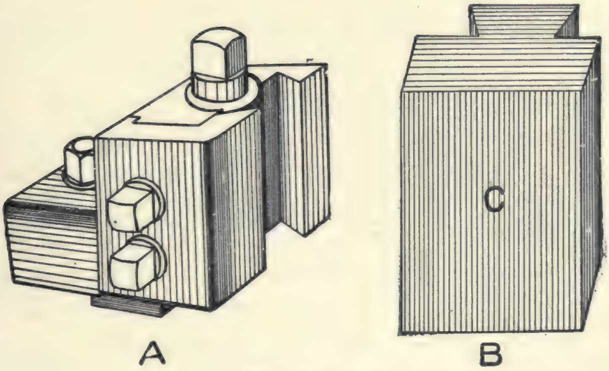


Fig. 153.

Circular Forming Tools are used very extensively on screw-machine and similar work. They are valuable on account of the ease with which any number of them may be produced, provided a forming tool is used in producing the shape on the face as shown in Fig. 154. After the blank has been formed to the desired shape, it may be milled as shown in Fig. 155 in order to provide a cutting edge. If it is desired to produce a shape on the piece being machined to correspond with the shape of tool, it is necessary to have the cutting edge radial as shown in Fig. 155. In order to feed the tool into the stock faster than can be done with the form shown in Fig. 155, it is given more clearance as shown in Fig. 156. On a tool whose cutting edge is not radial and will not produce a shape corresponding to its own, it is necessary when cutting the edge with the rake shown in Fig. 156, to make the face of the tool slightly different in form from that desired.

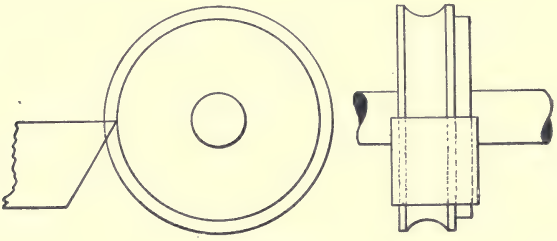


Fig. 154.

After milling the cutting edge, the name or number of the tool may be stamped on it, after which it is ready for hardening. When extremely high carbon steel is used, the tools sometimes crack while hardening from the strain incident to their shape. In order to overcome this tendency, some tool makers make two extra cuts in the edge as shown in Fig. 157, in order that the hardened edges may not be cracked from the contraction. Two cutting edges, as shown in Fig. 158 are often given tools in order that it may not need to be ground as often as when it has but one cutting edge. It is not necessary to stop the screw machine nearly as long to grind both cutting edges, as to stop the machine twice to grind the same edge on account of the time necessary to rig up the grinder.

When hardening, the tool should be heated to a low red and plunged in a bath of water or brine from which the chill has been removed; it should be worked around well in the bath. If the temper is not to be drawn after hardening, the tool may be held over the fire after removing from the bath and heated sufficiently to remove the tendency to crack from internal strains.

On account of some weak projection, which, because of its shape is likely to break when used, it is sometimes necessary to draw the temper. It is not always necessary to draw the temper to a straw color, and as a light straw is the first temper color visible, some other means must be employed. The tool may be placed in a kettle of oil, and by means of a thermometer any degree of heat may be obtained. The writer recalls a certain forming tool which was too brittle when left as it came from the hardening bath, yet was not hard enough when drawn to even the faintest straw color. When taken from the hardening bath, it was placed in a kettle of boiling water and left there about five minutes. The heat of the water at 212° reduced the brittleness

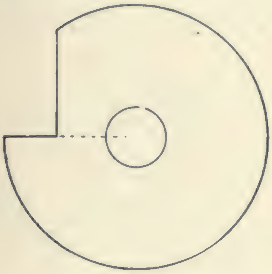


Fig. 155.

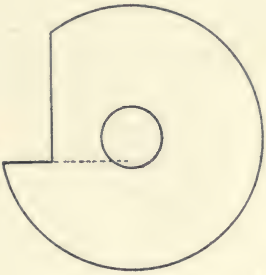


Fig. 156.

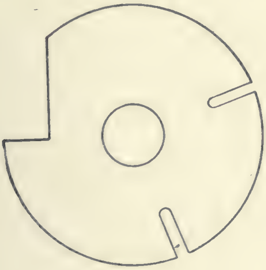


Fig. 157.

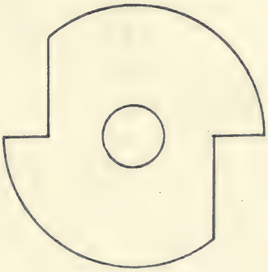


Fig. 158.

so that the tool stood up in a good shape, yet it did not perceptibly soften it.

The following is an excellent plan: Use a bath of water having about one inch of oil on top; the tool after being heated red hot is plunged down through the oil into the water. Enough oil adheres to prevent the sudden shock which the steel received when plunged into the cold bath.

"Pack Hardening" also gives excellent results.

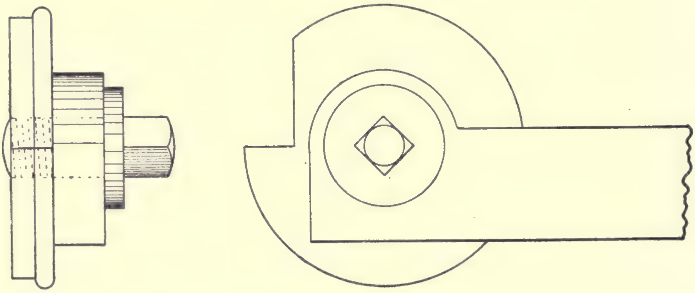


Fig. 159.

Tool Holders. The form of the holder for the tool depends on the class of work to be done and the machine in which it is to be used. Fig. 159 shows a design commonly used for hand screw machine work. If the cuts are comparatively light, the side of the tool and holder may be flat as shown. If, however, heavy cuts are taken which would have a tendency to turn the tool, it is often made with a taper projection on one side as shown in Fig. 160, the holder having a corresponding taper hole to receive the projection. This projection should be a good fit in the taper hole, but should not go in far enough to strike the bottom, neither should the side of the tool bear against the side of the holder.

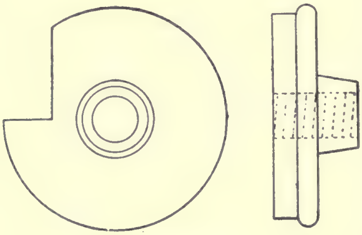


Fig. 160.

When used in automatic screw machines the holder is generally of a different shape from that used for hand screw machines.

A very common form is shown in Fig. 161. This holder is made in the form of an angle iron. The fixture (holder) is fastened to the tool rest by means of the bolt shown. The tool is fastened to the upright side of the holder by means of the bolt represented with its head let into the forming tool.

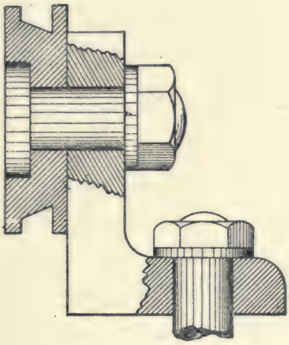


Fig. 161.

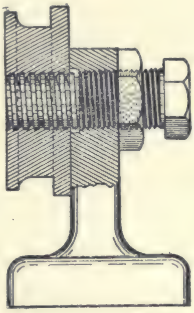


Fig. 162.

When extra heavy cuts are to be taken with a forming tool, it is sometimes considered advisable to make a holder of the form shown in Fig. 162. The holder is bolted to the tool rest in the same manner as the one represented in Fig. 161. A square thread having a pitch of five or six threads to the inch is cut in the forming tool; the thread should be right or left hand depending on which side of the machine the tool is to be located when in use, the thread being such that the tool will tighten by the pressure exerted by the cut. To get an adjustment, the thread in the holder must be of a finer pitch than that in the forming tool and of the same hand. If desired, this tool may be used in the ordinary form of holder shown in Fig. 161 by use of the bolt shown in Fig. 163.

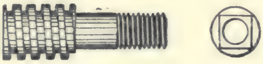


Fig. 163.

MILLING CUTTERS.

Milling machine cutters are made in two different forms: solid and with inserted teeth. It is customary in most shops to make cutters up to 6 or 8 inches in diameter solid, and above this size they are made with inserted teeth.

SOLID CUTTERS.

When making solid cutters it is advisable to use steel somewhat larger than the finish diameter of the cutter. A hole should be drilled in the blank $\frac{1}{16}$ inch smaller than the finish size of hole and the outside surface should be turned off. After annealing, it should be put in the chuck on the lathe, the hole bored and reamed to size and the hole recessed as shown at C in the sectional view of Fig. 164.

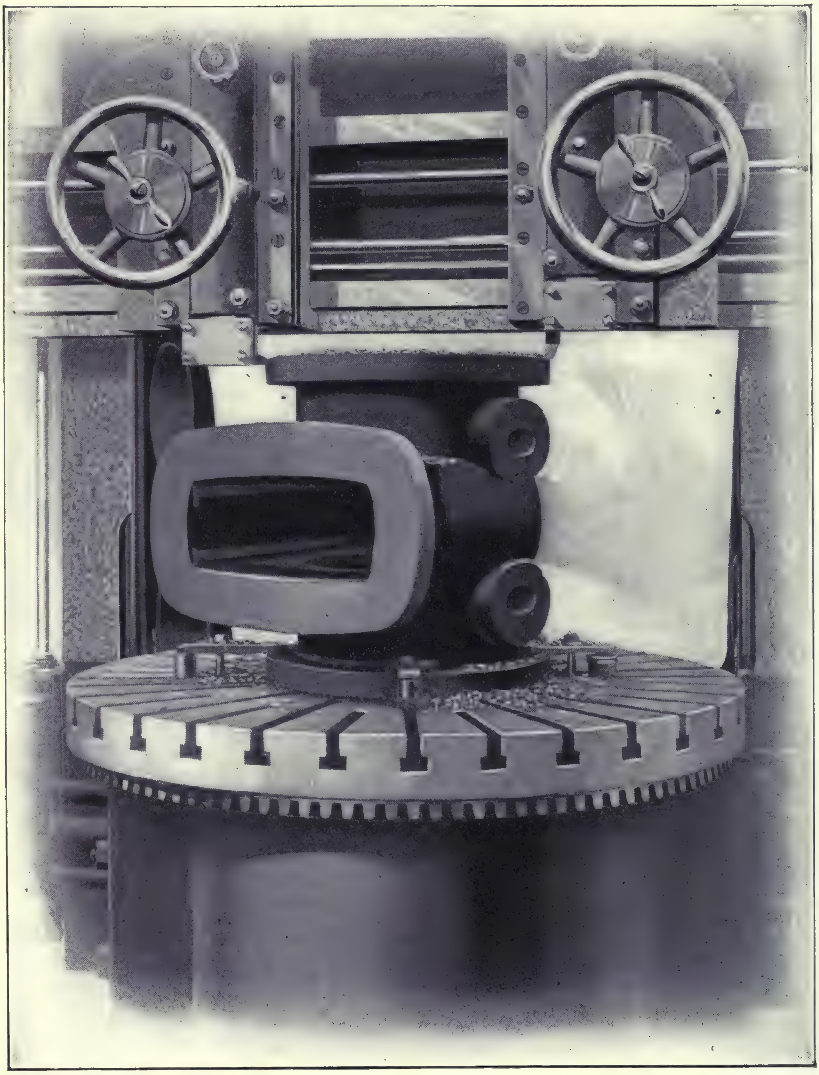
The piece should now be placed on the mandrel, and turned to the proper diameter and length. The teeth should be cut in the universal milling machine, or in a milling machine provided with a pair of index centers. The number of cutting edges for solid milling cutters varies somewhat according to the nature of the work to be done, but for general shop use the following table will be found satisfactory.

CUTTING EDGES FOR MILLING CUTTERS.

Diameter of Cutter.	No. of Cutting Edges.	Diameter of Cutter.	No. of Cutting Edges.
½	6	2½	20
¾	8	3	24
1	10 or 12	3½	26
1¼	14	4	28
1½	16	5	30
2	18	6	32

For most work it is desirable to have the faces of the teeth radial as shown in Fig. 164. However, when milling cutters are made to run in the direction of the feed or onto the work instead of against it, the teeth should be given a negative rake (cut ahead of the center) as shown in Fig. 165, as it has a tendency to keep the piece being milled from drawing toward the cutters.

When cutting the teeth, it is necessary to use a cutter that gives sufficient depth of tooth to provide a receptacle for chips, and also gives a form that supports the cutting edges. A cutter may be used that will produce an angle of about 50° between the



BORING AND TURNING MILL.

Facing Flange of Valve, Using Both Heads.

Bullard Machine Tool Company.

face and back of the tooth as shown at A in Fig. 164. The cutter should cut deep enough to leave the lands about $\frac{1}{32}$ inch in width at the cutting edges.

The form of cutter shown in Fig. 164 is known as a Side Milling Cutter. When cutting the teeth on the sides, it is necessary to put the cutter on a plug whose upper end does not project much above the top face of the cutter; this plug may be made straight and held in the chuck on the end of spindle in the spiral head. Such a plug is shown in Fig. 166 inserted in the cutter. If *many* cutters are made with teeth on the sides, it is advisable to make an expanding arbor, Fig. 167, whose shank fits the taper hole in the spindle of the spiral head. When milling the teeth on the sides, the index head must be inclined a little so that the side of the mill will stand at a small angle from the horizontal in order that the lands of the teeth may be of equal width at each end. The amount of this inclination cannot readily be computed.

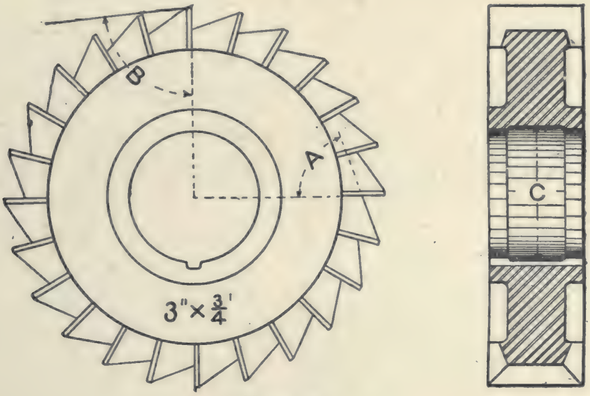


Fig. 164.

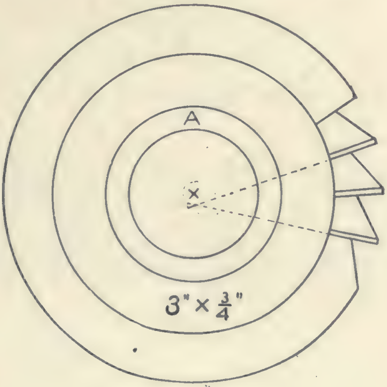


Fig. 165.

It is formed by first cutting a tooth leaving the cut somewhat shallow, then turning to the next tooth. After cutting the second tooth, the change in inclination will be apparent.

When the teeth are cut and the burrs removed, the diameter and length of the cutters may be stamped as shown in Fig. 164. The cutter is now ready for hardening. To successfully harden, it is necessary to have a *low*, *uniform* red heat; the teeth must be no hotter than the portion between the hole and the bottom of the teeth. When held toward the light there should be no trace of black in the interior of the cutter. When a uniform heat no higher than is necessary to harden the steel has been obtained, the cutter may be plunged into brine from which the chill has been removed; it should be worked around rapidly in the bath until the singing has ceased. It should then be removed from the brine and immediately plunged into oil and allowed to remain there until cold. When cold, the cutter may be taken from the oil and heated sufficiently to prevent cracking from internal strains. The cutter may now be brightened and the temper drawn to a straw color.

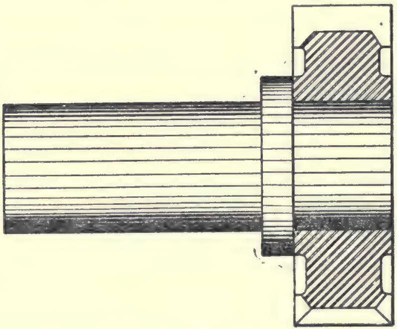


Fig. 166.

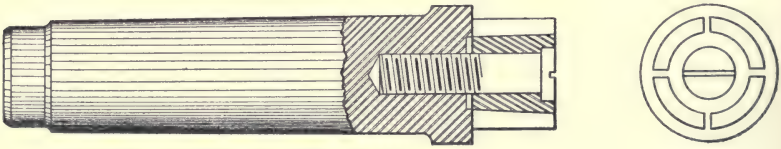


Fig. 167.

Grinding the Hole to *Size*. It is customary to ream the holes in milling cutters to size, and if the cutter contracts in hardening, the holes are brought to size again by lapping with a lead or cast iron lap, by means of oil and emery. However, this operation does not provide for the enlarging of the hole. While this is an unusual occurrence, it *sometimes* happens, and as a consequence the cutter does not fit the milling machine arbor and cannot do as good or as much work as it should.

On account of the necessity of having a correct fit on the milling machine arbor, it is advisable to ream the hole of the cutter with a reamer about .005 inch under the size of the arbor and finish by grinding after the cutter is hardened.

When grinding the hole to size, the cutter may be held in a chuck and ground with a small emery wheel, using the internal grinding attachment as shown in Fig. 168. This attachment is so designed that it may be swung out of the way when gauging the size of the hole as shown in Fig. 169. After grinding the hole to size it is advisable to grind the shoulders on each side of the cutter straight and true with the hole in order to prevent any possibility of springing the milling machine arbor by any untruth on the part of the cutter, and to prevent any possibility of the cutter running out of true. The shoulder (or boss) referred to is shown in A, Fig. 164.

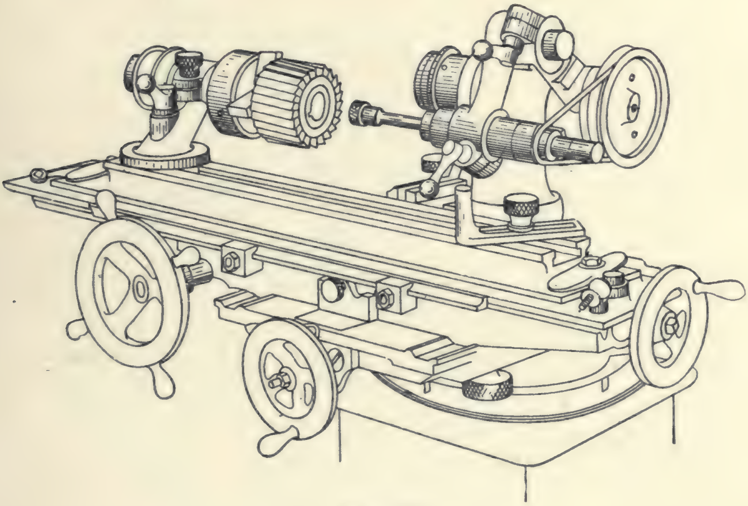


Fig. 168.

There are two methods of grinding the shoulders. By one method the outer shoulder and the hole are ground at the same setting; if this is done properly this shoulder will be true with the hole. The chuck is now removed from the grinder and a face plate having an expanding plug is put in its place. The shoulder that has been ground is placed against the face plate with the expanding plug in the hole of the cutter. The outer shoulder may be ground after the plug is expanded until the cutter is held rigidly in place against the face plate which should run perfectly true.

By the other method both shoulders are ground while on an arbor which is necked down each side of the cutter as shown in Fig. 170. This necking allows the wheel to traverse the whole length of the shoulder and not cut into the arbor, as would be the case if an ordinary mandrel were used.

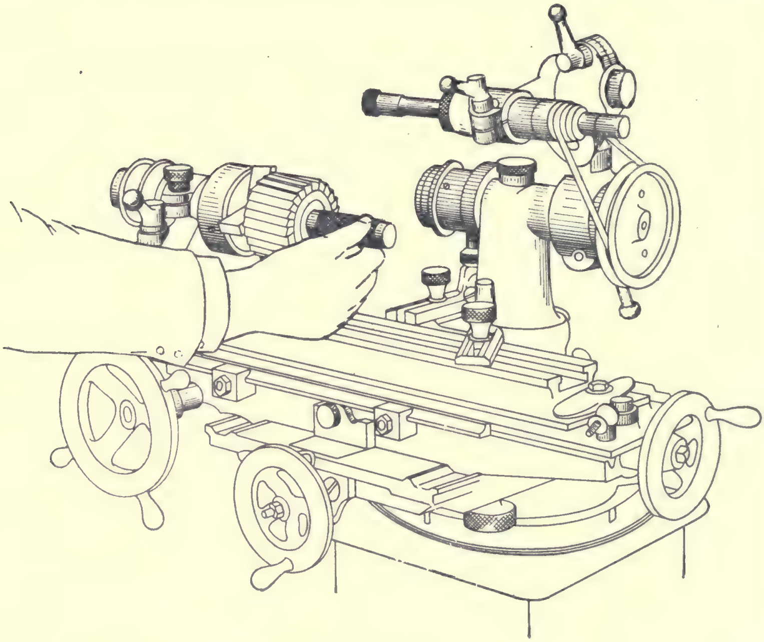


Fig. 169.

Grinding. In order to get the best results from a milling cutter it is necessary to use some form of grinder having a means of properly locating each tooth as it is presented to the wheel. This is usually accomplished by a finger which may be adjusted to the proper height to produce the required amount of clearance. The teeth may be given a clearance of about 3° as shown at B, Fig. 164. With this amount of clearance the cutter works freely and retains its edge; if more clearance is given the cutter is likely to shatter, and the edges of the teeth will become dull rapidly.

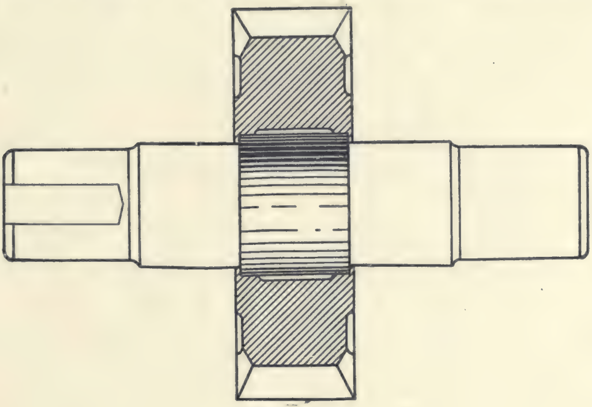


Fig. 170.

Fig. 171 shows a cutter in position for grinding the teeth; it will readily be seen that the tooth being ground rests on the finger or tooth rest; this finger may be adjusted to give any desired amount of clearance to the tooth. For grinding the teeth on the *side* of a milling cutter, a small emery wheel may be used in order to get the necessary amount of clearance without touching the tooth next to the one being ground.

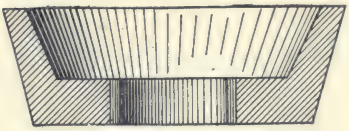


Fig. 172.

If a grinder is used which will take a cup wheel as shown in Fig. 172, and whose table can be turned to bring the cutter in the position shown in Fig. 173, a form of clearance is given the tooth which is more satisfactory than if ground with a small wheel. With the cup wheel the line of clearance is straight, while with the small plain wheel it is hollowed out, and as a consequence the cutting edge is weak.

Spiral Milling Cutters. It is customary in most machine shops to make all milling cutters of more than ½ inch face with teeth cut spirally as in Fig. 174. The amount of spiral given the teeth varies in different shops and on different classes of work.

The object of providing spiral teeth is to maintain a uniformity of cutting duty at each instant of time. With teeth parallel to the cutter axis, the tooth on meeting the work will take the cut its entire length at the same instant, causing a jump to the work on account of the springing of the device holding the work, and of the cutter arbor. If the teeth are cut spirally, the cut proceeds gradually along the whole length of the tooth, and after the cut is started a uniform cutting action is maintained, producing smoother work and a truer surface, especially in the case of wide cuts.

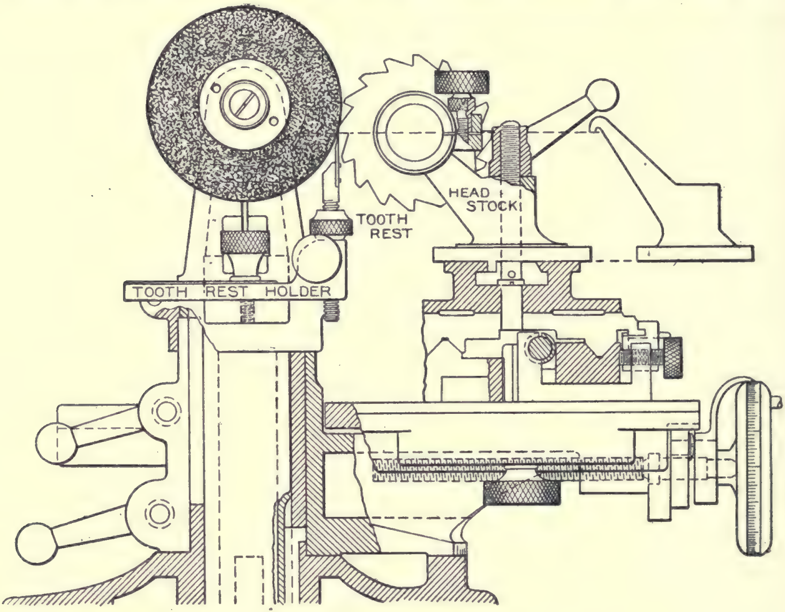


Fig. 171.

Milling cutters may be cut with either a right or left hand spiral, or helix, although it is generally considered good practice to cut a mill having a wide face with a spiral that will tend to force the cutter arbor into the spindle rather than to draw it out; then again, it is better to have the cutting action force the solid shoulder against the box, rather than to draw the adjusting nut against the box.

Where two very long mills are used on the same arbor and it is found necessary to cut them with a quick spiral, one cutter is sometimes cut with a right hand spiral and the other with a left hand spiral, in order to equalize the strain and reduce the friction resulting from the shoulder of the spindle pressing so hard against the box.

Special care should be taken in cutting spiral milling cutters that the work does not slip. When a cut has been taken across the face of a cutter it is best to lower the knee of the milling machine, thus dropping the work away from the mill while coming back for another cut; the knee can then be raised to its proper position which may be determined by means of the graduated collar on the elevating shaft of the machine.

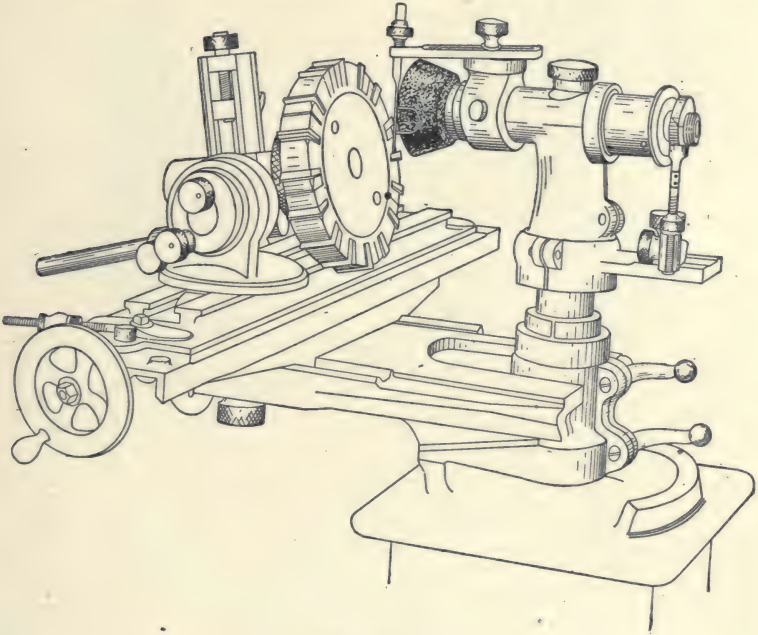


Fig. 173.

As it is important that the face of the cutting tooth be radial and straight, it will be found necessary to use an angular cutter of the form shown in Fig. 175, as cutters of this form readily clear the radial face of the cut and so remain sharp longer and produce a smoother surface to the face of the tooth than if cut with an angular cutter of the form used for cutting teeth which are parallel to the cutter axis.

The angular cutters for spiral mills are made with either 40°, 48° or 53° on one side and 12° on the other.

By setting the cutter, as shown in Fig. 175, so that the distance A is one twelfth the diameter, the face cut by the 12° side of the angular cutter will be nearly radial for the usual proportions.

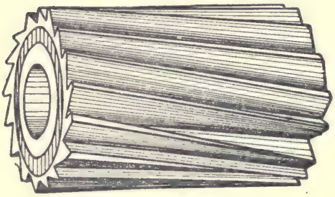


Fig. 174.

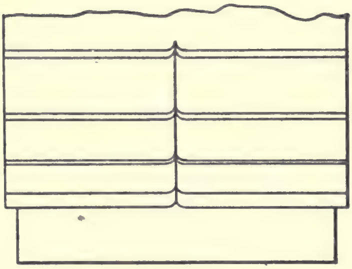


Fig. 176.

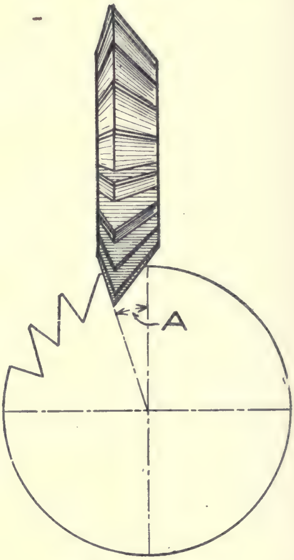


Fig. 175.

The setting for cutting the teeth of a spiral cutter must be made before turning the spiral bed to the angle of the spiral.

Milling Cutters with Interlocking Teeth. When two milling cutters of an equal diameter are to be used on the same arbor in such a manner that the end of one cutter is against the end of the other, the corners of the cutting teeth are likely to break away leaving a projection — or fin — on the work as shown in Fig. 176. In order to overcome this, part of the teeth are cut away on the sides of the cutters; that is, a tooth will be cut away on one cutter and the corresponding tooth on the other cutter will be left full length to set into the recess formed by the cutting away of the tooth. In some shops it is customary to cut away every other tooth while in others two, three or four teeth, will be cut away and an equal number left. Fig. 177 represents a pair of mills having every other tooth cut away, while Fig. 178 represents a pair having four teeth cut away.

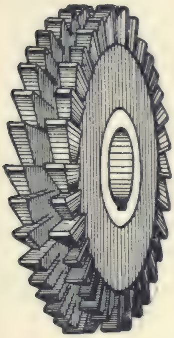


Fig. 177.

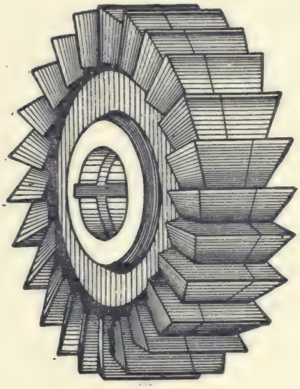


Fig. 178.

In order to cut away the teeth to make the cutter of a form having interlocking teeth, the cutter should be placed on a plug or expanding arbor as described for milling teeth on sides of side milling cutters. By means of a milling cutter having the proper width, the teeth may be milled away, although in case a cutter having several teeth cut away as shown in Fig. 178, it is well to use a narrow cutter and after taking one cut turn the index head so that the next tooth is in position. Continue doing this until the desired number of teeth are cut away. The index head may now be turned to pass over the required number of teeth and the operation repeated.

It is necessary when making cutters with interlocking teeth (sometimes called dodged-teeth) that the milling be deep enough to prevent the corresponding tooth on the other part of the cutter from striking the bottom of the recess. The parts of the cutter should bear against each other on the shoulders, or hubs.

An excellent form of milling cutter to be used for milling slots or similar work may be made as shown in Fig. 179. This form is less expensive to make than one having interlocking teeth and answers the purpose as well. It is necessary to make an eccentric mandrel of the design shown in Fig. 180 having the eccentric centers on opposite sides of the regular centers as shown. The two pieces which make the cutter should be cut from the bar long enough to finish the thickness of the heaviest part A A, Fig. 179. The hole is made $\frac{1}{16}$ inch smaller than finish size, the outside surface turned off and the pieces annealed.

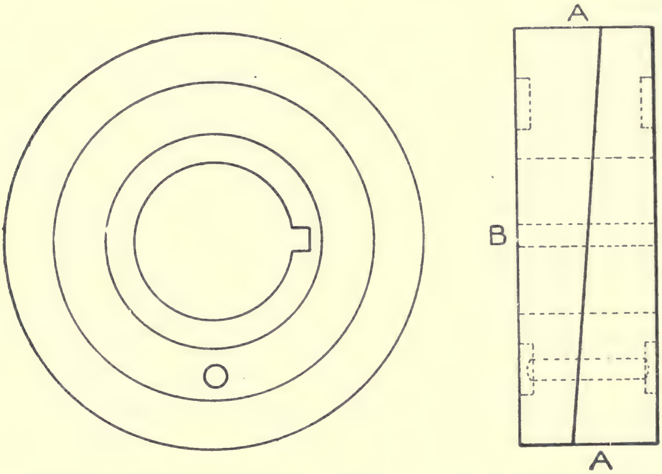


Fig. 179.

After annealing, the hole may be made the desired size for grinding. One of the pieces may then be placed on the eccentric mandrel, forcing it on until the side that is to be beveled is exactly in the center of the mandrel. The side B may be machined with the mandrel running on the regular centers while the beveled side must be machined with mandrel running on the eccentric centers. When the arbor is running on these centers, a distance half way between the two ends runs true; it is at this point that the side of the blank to receive the bevel should be located as shown in Fig. 181 provided the eccentric centers are of an equal depth. After machining the two parts of the cutter to shape, they should be so placed on a stud that the two beveled sides will be next each other as shown in Fig. 179, and the thinnest part of one next to the thickest part of the other. The pin hole may now be drilled and reamed for a $\frac{3}{16}$ inch pin which should be inserted. The blank is next placed in the vise on the shaper or planer and the spline slot cut as shown. It is now ready to be milled. After the cutter is hardened, the beveled sides may be ground true, the halves put together, hole ground to size, and the cutter ground to thickness, after which the teeth may be ground for clearance. If it is found necessary to increase the width of the slot, it may be done by shimming between the two parts of the cutter with paper or thin sheet metal; the design of the cutter allows this to be done without leaving any *fin* in the slot.

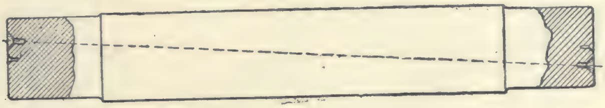


Fig. 180.

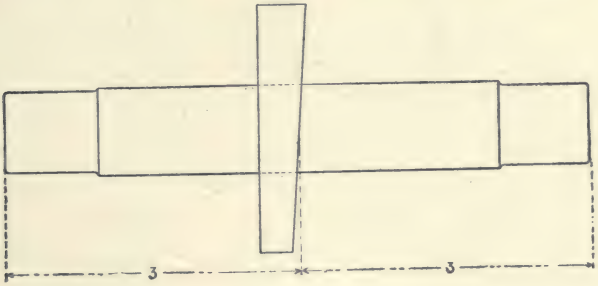


Fig. 181.

Nicked Teeth. Spiral cutters with nicked teeth, Fig. 182, are especially adapted for heavy milling. As the chip is broken up a much heavier cut can be taken than would be possible were an ordinary cutter used. The nicking may be done as follows: An engine lathe may be geared to cut a thread of the required pitch — two threads to the inch will be found satisfactory — and with a round nose tool $\frac{1}{8}$ inch wide cut a thread of sufficient depth that it may not grind out before the teeth will become too shallow to allow further grinding. This thread should be cut before milling the spaces to form the teeth.

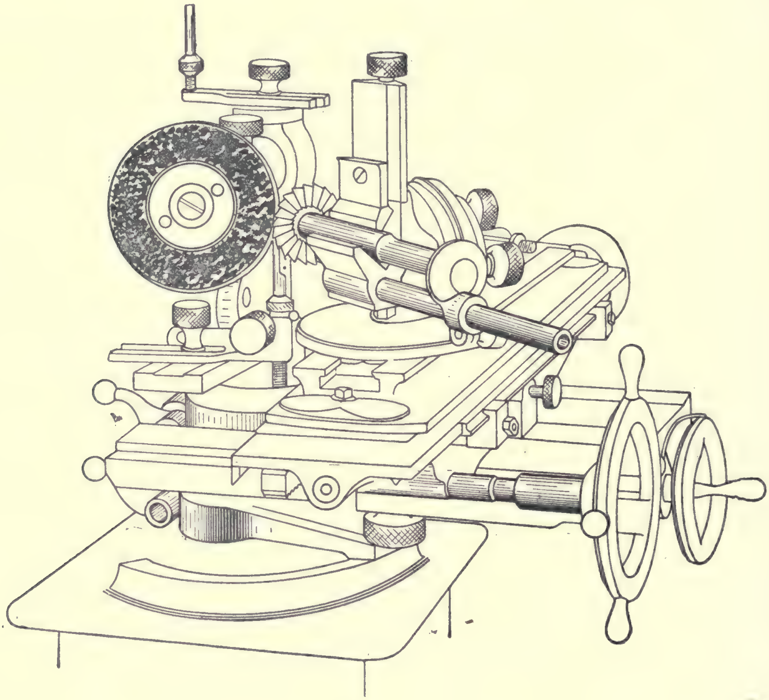


Fig. 183.

Angular Cutters. When making angular cutters the same general instructions given for making solid straight cutters should be followed except that the desired angle should be given.

When milling the spaces which form the teeth, the index head is set at an angle that will cut the edge of the tooth of an equal width its entire length. After removing the burrs the cutter may be hardened and tempered. The hole should be ground to size and the sides ground true with the hole. It should then be placed on a mandrel or stud and the teeth ground for clearance. Fig. 183 shows the method used in grinding the teeth of a mill of this form.

MILLING CUTTERS WITH INSERTED TEETH.

When milling cutters exceed 6 or 8 inches in diameter, it is generally cheaper to make the body of cast iron or machinery steel and insert in the periphery teeth made of tool steel. There is a variety of methods for holding the teeth in place. If the cutter is narrow, or is to be used as a side milling cutter, the grooves to receive the teeth may be cut straight (parallel to the cutter axis) as shown in Fig. 184. If the cutter face is over one inch long, the slots to receive the teeth should be cut in such a manner that spiral teeth may be used.

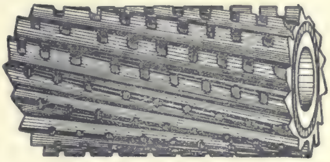


Fig. 182.

While it is a comparatively easy matter to cut the slots spirally, it is difficult to make the teeth of a shape that will fit the spiral slots without the aid of special tools. Consequently the slots are generally milled at an angle to the cutter axis, having the side of slot that corresponds to the face of the tooth equidistant from a radial line at each end of the cut. The face of the

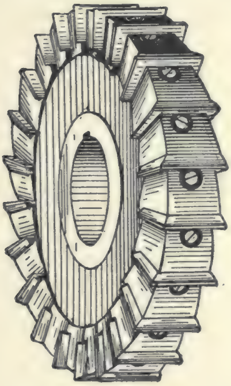


Fig. 184.

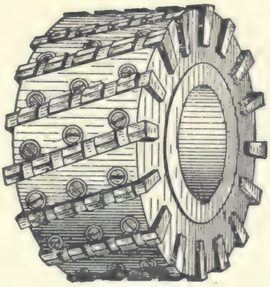


Fig. 185.

slot at one end would be ahead of the center, while at the opposite end it would be behind the center; this is termed a front rake, and a negative rake respectively.

The slots should be cut somewhat wider than would be necessary were the teeth to be made of a spiral form. After turning to size, the faces of the teeth may be milled spirally to make them radial.

If the mills are intended for heavy work, the teeth may be nicked as already described. The coarse pitch thread should be cut before the teeth are milled spirally.

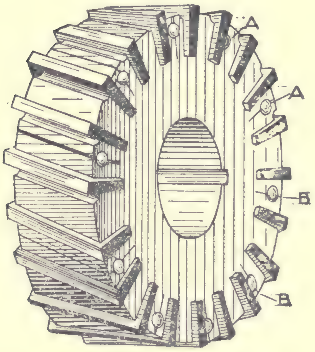


Fig. 186.

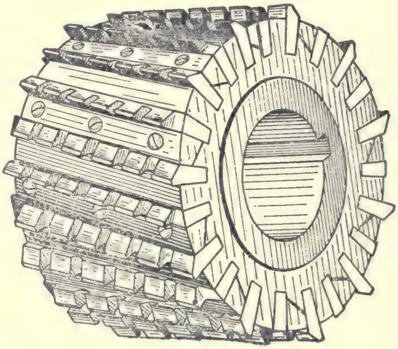


Fig. 187.

After hardening, the teeth may be put in place and fastened; they are now ready for grinding. The emery wheel for grinding milling machine cutter teeth should be of the proper grade as to hardness and coarseness; if the wheel is very *hard* or *fine*, it will be likely to draw the temper at the cutting edges of the teeth; the emery should not be coarser than No. 60 or finer than No. 90.

If the face of the wheel is glazed, remove the glaze with a piece of emery wheel somewhat harder than the wheel in use; this not only removes the glaze but makes the surface of the wheel more open and less likely to glaze. The emery wheel should run *true;* its face should not exceed $\frac{1}{4}$ inch in width. Generally speaking, the softer the emery wheel the *faster* it should run, but the peripheral speed should not exceed 5,000 feet per minute.

Fastening. There are several methods for fastening the teeth in this form of cutter, any one of which gives satisfaction if the work is well done.

The method illustrated in Fig. 186 is in use in the works of the Pratt and Whitney Co., of Hartford, Conn. In this design, between every second pair of teeth a hole is drilled and reamed taper to receive the taper pins A A, after which the slots B B are cut with a thin cutter. After the cutters are in place the taper pins A A are driven into the holes, thus locking the cutters. To remove the cutters the pins are driven out.

A method of fastening the cutters which are used by the Morse Twist Drill & Machine Co., of New Bedford, Mass., is shown in Fig. 187. In this case the stock between every second pair of teeth is milled away not as deep, however, as the slots for the cutters. Wedge-shaped pieces of steel are fitted between the teeth as shown. When these are drawn to place by means of fillister headed screws they bind the cutters very securely. If the wedge-shaped binding blocks touch the bottoms of the slots they will not hold the cutters securely in place.

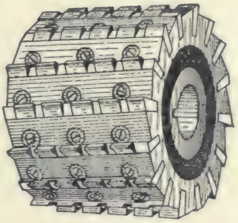


Fig. 188.

The method shown in Fig. 188 is used by Brown & Sharpe Mfg. Co. of Providence, R. I. The teeth are held in place by taper bushings and screws as shown.

Standard Key Ways. To prevent milling machine cutters turning on the arbor when cutting, it is necessary (especially when taking heavy cuts) to have key ways cut as shown in Fig. 189.

The arbor, of course, must have a similar slot to receive the key. It will be noticed that the dimension D refers to the diameter of the *hole* in cutter, and not to the diameter of the *cutter*.

Formed Cutters. As used by the Brown & Sharpe Mfg. Co., the term "Formed Cutter" applies to the cutters with teeth so relieved that they can be sharpened by grinding without changing their form. However, the term "Form Cutter" can be applied to any cutter cutting a form regardless of the manner in which the teeth may be relieved. Fig. 190 represents a formed cutter.

Formed cutters are used in many shops where work of irregular shape is milled in large quantities, as in sewing machine, gun and bicycle shops.

While this style of cutter can be made to better advantage in a shop equipped with machinery designed especially for this class of work, an ordinary engine lathe can be converted to a *backing-off lathe* for relieving or backing off the cutters. Or, a comparatively inexpensive fixture (known as the Balzar backing-off device) may be used. However, a simple arrangement consists of an eccentric arbor operated by a hand lever, or a stud may be screwed in the faceplate of a lathe ; the cutter is placed on this stud in a position that allows the teeth to be given the necessary amount of clearance. When backing off the teeth of cutters whose faces do not exceed 1 inch in width the Balzar backing-off fixture shown in Fig. 191 can be used to advantage. This device

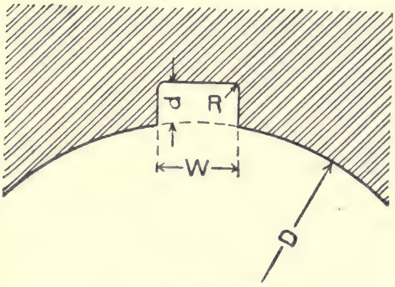


Fig. 189.

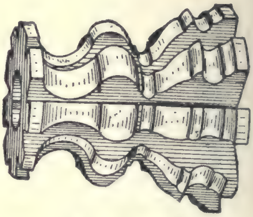
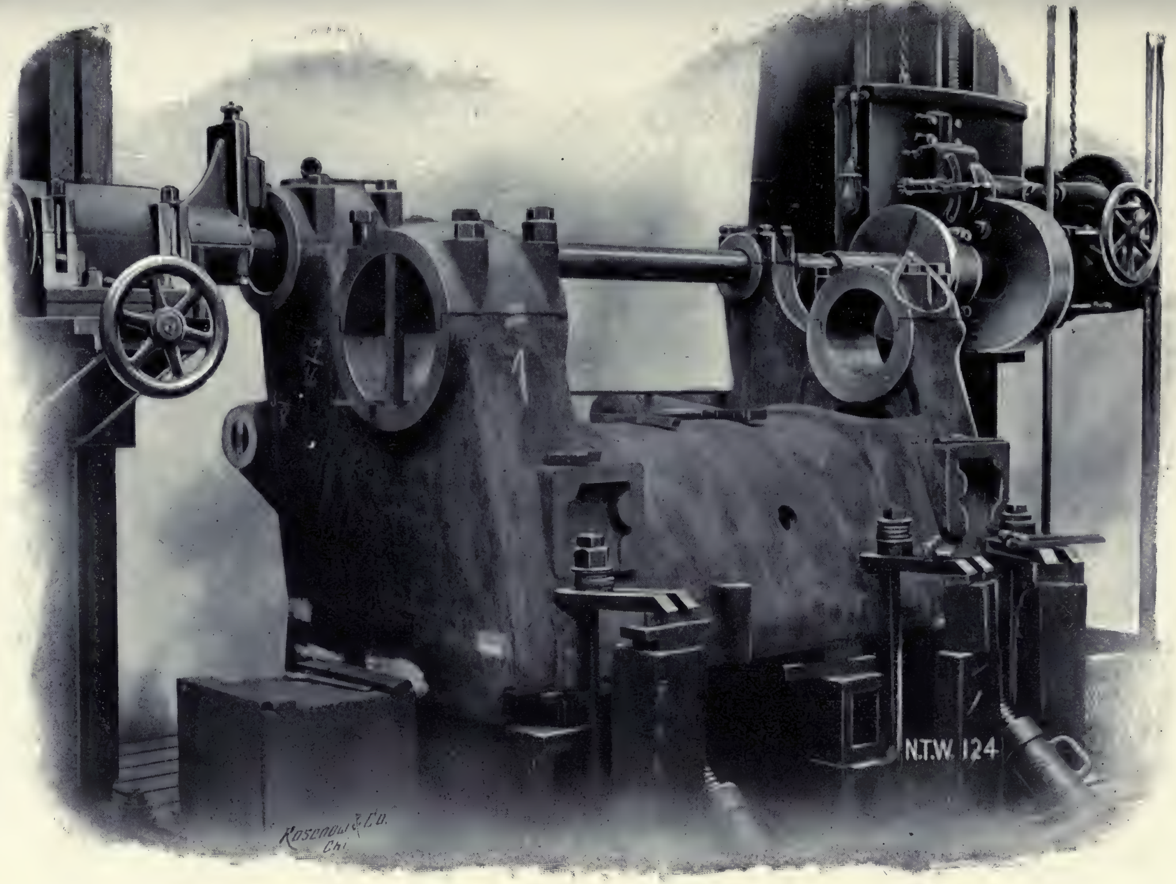


Fig. 190.

STANDARD KEY WAYS FOR CUTTERS.

Diameter (D), Inches.	Width (W), Inches.	Depth (d), Inches.	Radius (R), Inches.
$\frac{3}{8}$ to $\frac{9}{16}$	$\frac{3}{32}$	$\frac{3}{64}$	.020
$\frac{5}{8}$ to $\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	.030
$\frac{15}{16}$ to $1\frac{1}{8}$	$\frac{5}{13}$	$\frac{5}{64}$	.035
$1\frac{3}{16}$ to $1\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{32}$	.040
$1\frac{7}{16}$ to $1\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	.050
$1\frac{13}{16}$ to 2	$\frac{5}{16}$	$\frac{5}{32}$	.060
$2\frac{1}{16}$ to $2\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$	.060
$2\frac{9}{16}$ to 3	$\frac{7}{16}$	$\frac{3}{16}$	.060



BORING AND FACING HEADSTOCK OF LATHE.
Niles-Bement-Pond Co.

is held between the centers of a lathe in the ordinary manner, the backing off being such that the cutter can be ground without alteration of shape. The tool is so constructed that it is only necessary to place the cutter upon the arbor in the ordinary way. Place the arbor on the lathe centers as shown, start the lathe and feed the forming tool in by the cross-feed screw in order to take the desired cut in the same manner as in plain turning. The ratchet connected with the arbor, and actuated by the pawl, contains ordinarily thirty-six teeth and the stroke can be set to back off a cutter with 9, 12, 18 or 36 teeth.

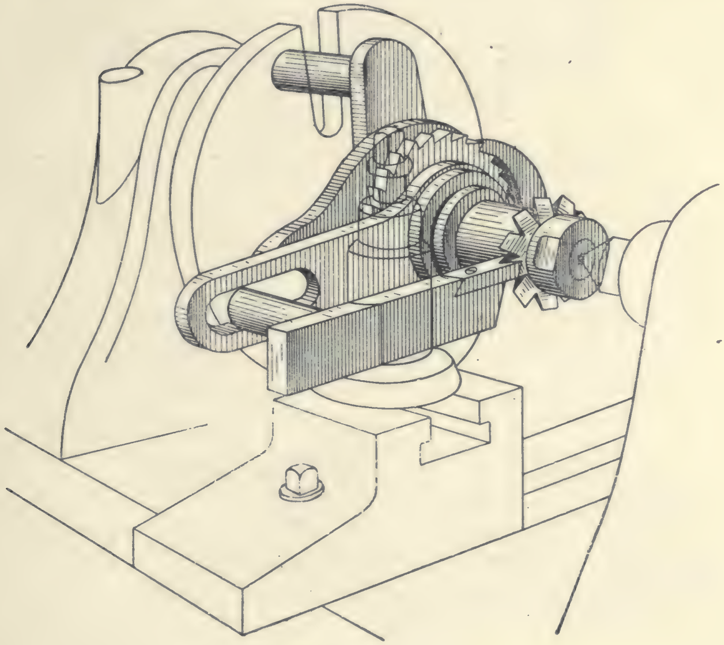


Fig. 191.

Backing off by an Eccentric Arbor. An arbor may be made having a pair of centers located to give the cutter tooth the required amount of clearance; such an arbor is shown in Fig. 192. The eccentric centers are shown at the sectional portions at the ends. The amount of eccentricity depends somewhat on the size of the cutter to be backed off; but for cutters not exceeding 4 inches diameter, from $\frac{3}{16}$ to $\frac{1}{4}$ inch will give excellent results.

The screw at the end of the arbor should be of a fine pitch; about 12 threads per inch for arbors 1 inch diameter. The object in cutting a fine pitch thread is, the cutter being backed off may be held more securely with the same amount of power exerted in tightening the nut; again the depth of thread is not as great as for a thread of coarser pitch, and as a consequence, the plane portion at the end of the arbor (which is made the size of the bottom of the thread) may be left large enough to get in a center hole of good size having $\frac{1}{4}$ inch eccentricity.

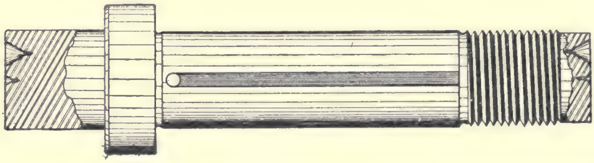


Fig. 192.

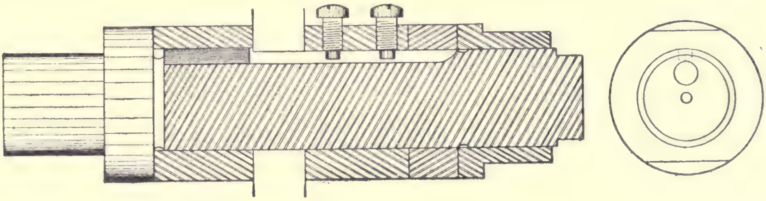


Fig. 193.

The spline cut should be at least $\frac{1}{8}$ inch wide and about $\frac{1}{8}$ inch deep; the walls of the cut should be parallel in order that the screws shown in Fig. 193 as passing through the collar and entering the slot in the arbor, may have a good bearing. These screws are to keep the collar from turning when the necessary power is applied to the nut when fastening the cutter in place. The collar on the opposite side of the cutter has a spline cut the same width as cut in the arbor, and is held in position by a spline as shown. The cutter cannot be held by a spline as it is necessary to move it each time a tooth is brought into position for backing off.

When machining the cutter blank, it is given the desired shape by means of a forming tool. If the shapes vary much in size the shape may be roughed out before using the forming tool. After it has been machined to the desired size and shape, it may be placed between the centers of the milling machine, and a number of grooves cut the entire length of the cutter. The number of grooves must correspond to the number of teeth the mill is to have; these grooves cannot be cut to finish width until after the teeth are backed off, because the forming tool cuts a trifle deeper at the point of contact, making it necessary to mill a small amount from the face of the tooth after backing off. The grooves are sometimes cut with a thin milling cutter, or a metal slitting saw $\frac{1}{8}$ inch thick. When a groove of this description is cut, the cutter has the appearance shown in Fig. 194. Cutting a groove of this form makes more work for the operator than when cut as shown in Fig. 195, in which the distance across the tops of the teeth is decreased by using an angular cutter of the shape shown in Fig. 196. After cutting the grooves the cutter may be placed on the eccentric arbor which is held between the centers of the lathe in the ordinary manner. A forming tool that will produce the desired shape of tooth is placed in the tool post; the top face of the tool must be set at the exact height of the center of the lathe in order to produce the proper shape. Fig. 197 shows an eccentric arbor

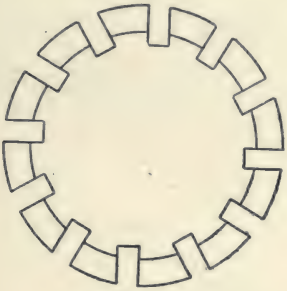


Fig. 194.

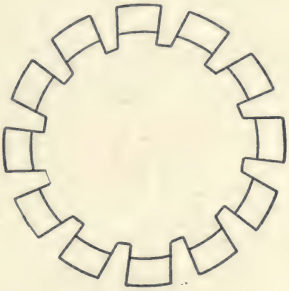


Fig. 195.

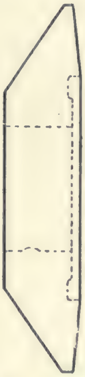


Fig. 196.

in a lathe in position to back off the teeth of a formed mill. The arbor is operated by means of the lever. The arbor is entirely independent of the spindle in its action, the eccentric centers being placed on the centers of the lathe, and the necessary motion given by means of the lever which strikes the carriage at the end of the stroke. In order to avoid bruising the lathe a strip of leather is attached to the lever as shown.

To set the cutter tooth in the proper location before backing off, a piece of thin sheet metal is placed on the top face of the tool, as shown in Fig. 198. The lever is brought down on to the carriage, the tooth of the cutter is brought down on to the sheet metal and the nut tightened. The tooth to be backed off is the one below that set to the thickness of the strip above the tool. The object in raising the tooth a given distance above the face is to prevent the one being backed from and striking the tool at the end of stroke. Again the teeth are set alike. This operation must be repeated for the setting of each tooth before backing off. The forming tool is fed by means of the cross-feed screw, a tooth

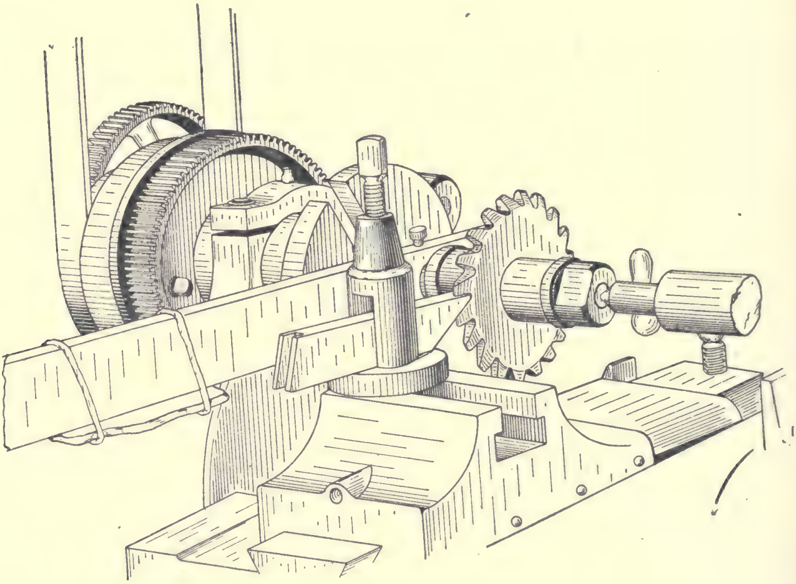


Fig. 197.

is backed off nearly the desired amount leaving a little for a finish cut; the tool is withdrawn, the nut loosened and the cutter turned on the arbor to bring the next tooth in position to be backed off. This operation may be repeated until all the teeth are backed off alike. The amount of backing off must be determined by the cross-feed stop, or a graduated dial on the cross-feed screw. After the roughing cut has been taken on all the teeth, the forming tool may be sharpened by grinding, or by oil stoning, and the finish cut taken on the teeth. Another method of backing off cutter teeth is shown in Fig. 199. A stud is screwed in the faceplate of a lathe near the outer edge as shown. The cutter which must be a fit on the stud is clamped by means of the nut shown. The finger A is movable in the slot in the stationary block B which is located on the face plate to bring the tooth to be backed off in its proper location, and keeps it from turning when being operated on. The forming tool is fed in gradually until the tooth is formed. The finger is then disengaged from the space in the cutter, which is revolved by means of the set screw until the next is in position.

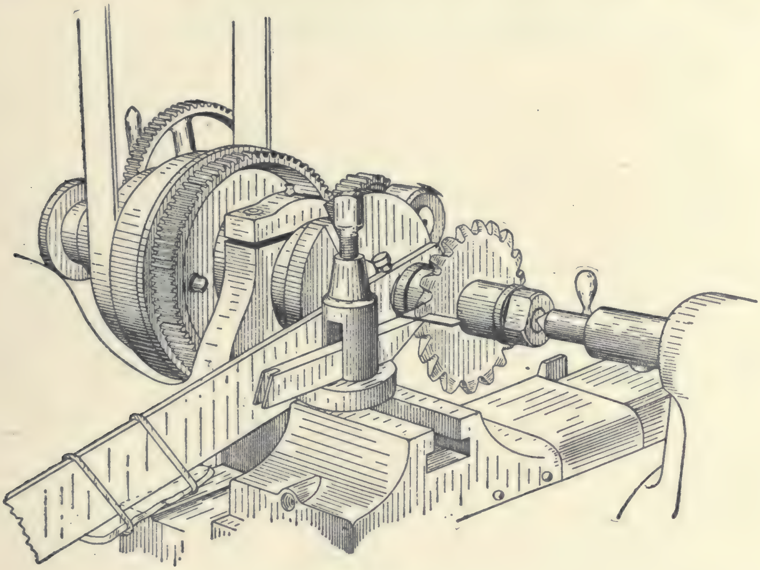


Fig. 198.

Each tooth is machined seperately, that is, the forming tool is fed in the required distance for each tooth when it is in position. The cutter is turned until the next tooth is in position, and the process repeated until each tooth has been backed off.

In backing off cutters in this device it is necessary to cut the notches (spaces between the teeth) somewhat wider than the teeth.

When backing off the teeth for clearance by any of the means described, it is first necessary to form the blank, then gash it or cut the notches as described; the teeth are now backed off.

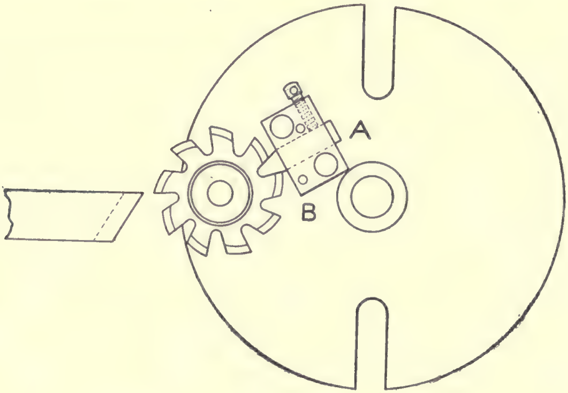


Fig. 199.

After backing off it is necessary to mill the face of the tooth back $\frac{1}{32}$ inch or so to cut away "the jump" (as it is termed) caused by the forming tool drawing in a trifle when it first strikes the edge of the tooth.

Threaded Holes. It is often necessary to make milling cutters with threaded holes. This happens in the case of *small* angular cutters, and many styles of cutters for use on profiling edge milling) machines.

The same general instructions for making the other forms of cutters apply to those with threaded holes, except that instead of reaming the hole to a given size the thread is cut with a tap of the proper size and pitch or it is chased in the lathe. After threading, the cutter should be screwed on to a threaded arbor.

Fig. 200 shows an arbor of this description. The end A is threaded slightly tapering for short cutters about .002 inch in 1 inch of length. On the taper end of the arbor a thread should be cut of a size that will not allow the cutter to screw on the arbor quite the entire length, that is, the cutter should overhang the threaded portion of the arbor a trifle (say one thread); this allows the outer end to be squared up without mutilating the threads on the arbor. The reason for using the *taper* end of the arbor when squaring the first end of the cutter is that the shoulder is true with the thread in the cutter. After squaring this shoulder, the cutter blank may be removed and placed on the opposite end of the arbor with the side that has been squared against the shoulder of the arbor. This method of machining pieces of work having a threaded hole, where it is desirable that the outer surfaces be true with the hole, is applicable to all classes of work. The cutter may be machined to length and shape on the straight end of arbor.

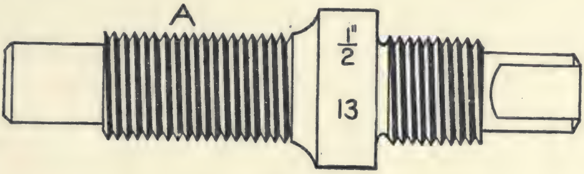


Fig. 200.

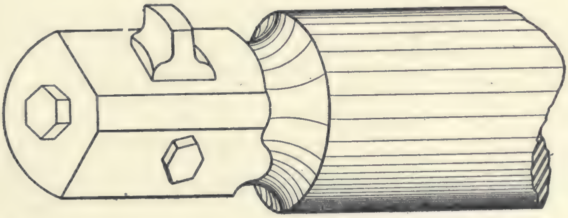


Fig. 201.

Fly Cutters. The simplest form of milling machine cutter is known as a fly cutter. It has only one cutting edge but is particularly valuable when making but one or two pieces of a kind for experimental work, and when making and duplicating screw-machine and similar tools of irregular shape.

As these cutters have but one cutting edge, they produce work very accurate as to shape, but cut very slowly and do not last as long as those having more teeth. However, they are used on *special work* on account of the small cost of making. It is necessary to hold the cutters in a *fly cutter arbor* which is shown in Fig. 201.

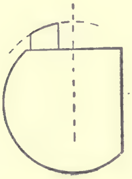


Fig. 202.

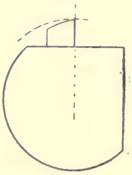


Fig. 203.

The cutter to be used in a fly cutter arbor may be filed to a templet, giving the necessary amount of clearance in order that the back edge, or keel, may not drag. If it is desirable to make the impression in the fly cutter with a milling cutter of the regular form, the piece of square steel from which the cutter is to be made may be held in the milling machine vise and the shape cut with the milling cutter. The desired amount of clearance may be given by holding the piece in the vise at an angle of a few degrees.

To make a fly cutter from a forming tool, the piece of steel may be held in the fly cutter arbor in such a position that the face is somewhat back of a radial line as shown in Fig. 202. After hardening the cutter may be set so that the cutting edge will be radial and the clearance will be as shown in Fig. 203.

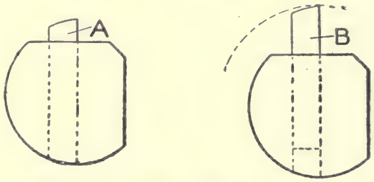


Fig. 204.

Another method of getting the clearance for the cutter is to place the top of the cutter blank as near the arbor as possible and then cut the desired shape. If the cutter is set in the arbor so that it projects from the surface it will have the necessary clearance as shown in Fig. 204. A represents the position of the blank while being cut and B the cutter in position for cutting; the dotted line showing the circle through which the cutting edge travels, the amount of clearance is apparent.

End Mills. This form of milling machine cutter (Fig. 205) is familiarly known as a **shank mill.** The term is used on account of the shank B which in small milling cutters fits into a collet. This collet in turn fits the hole in the spindle of milling machine. The collet referred to is used to save stock in making the cutters as otherwise it would be necessary to use steel large enough to make a shank of the size of hole in the spindle of the milling machine.

The cutter shown in Fig. 205 is what is termed a *left hand* mill; if the teeth run in the opposite direction, it is called a *right hand* mill.

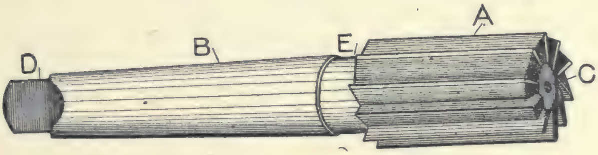


Fig. 205.

In making a shank (or end) mill of the form shown in Fig. 205 stock should be selected enough larger than the cutting end A to allow of turning off the decarbonized surface of the steel. After facing the ends to length, and turning the roughing chip, the end A may be run in the steady rest of the lathe and the center cut away — or recessed — as shown at C. The blank should be recentered and countersunk to furnish a center to use in turning the mill to size and shape. The object in cutting the center out as shown is to furnish a cavity for the angular cutter used in cutting the teeth on the end of the mill. Without this it would be impossible to grind satisfactorily.

After recentering the end C, the tenon D may be turned to size and milled to thickness, which should be a trifle ($\frac{1}{32}$ inch) less than the width of the center key slot in the collet. The taper at B should be turned enough larger than finish size to allow for grinding after the milling cutter is hardened. The cutter end A should be turned .010 inch larger than the required diameter. The portion E should be turned $\frac{1}{32}$ inch smaller than the large end of B or to dimensions if any are given on the drawings.

In order to insure teeth strong enough to resist the strain of cutting, an angular mill should be selected that will give the required shape. In Fig. 206 is shown a form of cutter tooth too weak for actual service; this tooth is the result of using an angular cutter with a cutting face forming an acute angle with the side. Fig. 207 shows a cutter whose teeth are strong, yet deep enough to be practical; these teeth were cut with an angular mill of less angle. Fig. 208 represents a cutter whose teeth were cut with the same cutter used for Fig. 206. The teeth were cut to the required depth first; this of course leaving them too thick at the cutting edges as shown in Fig. 209. After cutting the teeth as shown at A, Fig. 209, the index head was turned sufficiently to cut the teeth as shown at A, Fig. 208.

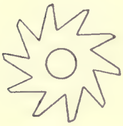


Fig. 206.

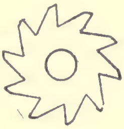


Fig. 207.

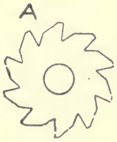


Fig. 208.

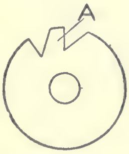


Fig. 209.

After cutting the teeth around the circumference of the mill, it should be placed in the collet and the collet put in the spindle hole in the spiral head in order to cut the teeth on the end.

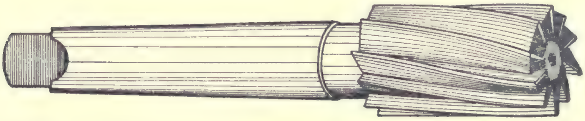


Fig. 210.

When cutting the teeth on the end of the mill, the spiral head is turned until the cutter is in a horizontal position. The angular cutter used should not have a very acute angle or the teeth will be weak. An 80° angular milling cutter will be satisfactory.

Spiral End Mills. It is sometimes advisable to cut the teeth of end mills spirally as shown in Fig. 210. As there is no support at the outer end of this form of mill it will be necessary to cut the teeth of a spiral that will have a tendency to force the mill into the collet rather than draw it out. Fig. 210 represents a left hand end mill cut with a right hand spiral.

End Mills with Center Cut. This form of End Mill is useful when it is necessary to cut into the work with the end of the mill, and then move along as in dies, cams, and grooves. The teeth being sharp on the outside, cut a path from the point of entrance. The coarser teeth allow a heavier cut, especially in cast iron. Fig. 211 shows two views of an end mill with center cut.

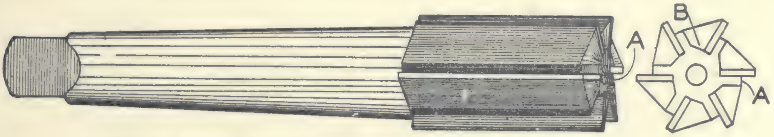


Fig. 211.

After cutting the teeth on the end with an angular cutter, a thin straight faced cutter of small diameter should be run through close to the face of the cutter tooth making a cut as shown at A; this cut should be of sufficient depth to permit of backing off the inner edge of the tool as shown at B. This clearance allows the mill to cut away the slight projection left in the center of mill when it is fed into a piece of work. Such a projection is shown at A in Fig. 212.

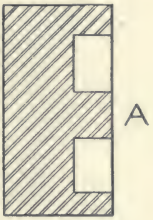


Fig. 212.

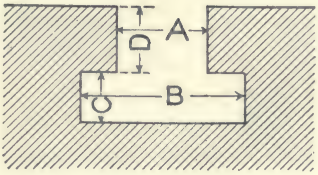


Fig. 213.

T-Slot Cutters. In cutting T slots in various parts of machines, such as milling machine carriages, etc., it is necessary to use a form of shank mill known as a T-Slot Cutter. Fig. 213 shows the ordinary form of T-slot; while Fig. 214 shows the cutter. A portion of the stock below the teeth is cut away as shown at A A in the sectional view Fig. 215. This is necessary in order to back off the teeth on the sides of the cutter for clearance, and to do away as far as possible with unnecessary friction when the cutter is working.

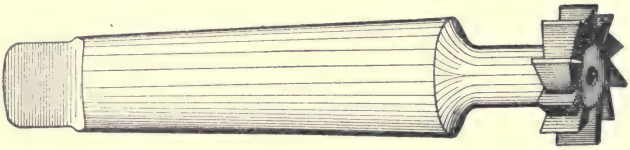


Fig. 214.

T-slot cutters are usually made $\frac{1}{32}$ inch larger in diameter than the size designated on the cutting portion to allow for sharpening; that is, a mill intended for cutting a slot $\frac{1}{2}$ inch wide is made $\frac{1}{2} + \frac{1}{32}$ or $\frac{17}{32}$ inch diameter, unless intended for cutting a slot to given dimensions.

It is advisable to harden mills of this description the entire length of the neck, especially if the neck is of small diameter; otherwise they will be very likely to spring when in use. After hardening, the neck should be drawn to a blue color, while the cutting part should be drawn to a straw color.

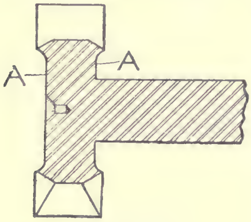


Fig. 215.

When grinding end mills, the shank in all cases should be ground first to fit the collet or holder, allowing it to enter *far enough* to key out readily, yet not enough to allow the shoulder above the tenon to strike the shoulder in the collet.

After grinding the teeth for clearance on the diameter, the teeth on the end should be ground. Most universal and cutter grinders are provided with a fixture for holding the mill by the shank while grinding these teeth; such a fixture is shown in Fig. 216.

Face Milling Cutters. This form of cutter is used in milling surfaces too large to be cut with the ordinary form of milling cutter held on an arbor passing over the work. As the full diameter of the face of the cutter may be used, it may have less than one half the size that would be necessary for a side milling cutter. A side milling cutter must be double the diameter of the surface to be cut plus the diameter of the collar on the arbor. For instance if a surface as A, Fig. 217, were to be milled, it would be necessary to use a cutter somewhat larger in diameter than twice the height of the surface plus the diameter of collar B. Whereas if a *face* milling cutter of the form shown in Fig. 218 were used the diameter need not be much greater than the height of the face of the piece of work being milled.

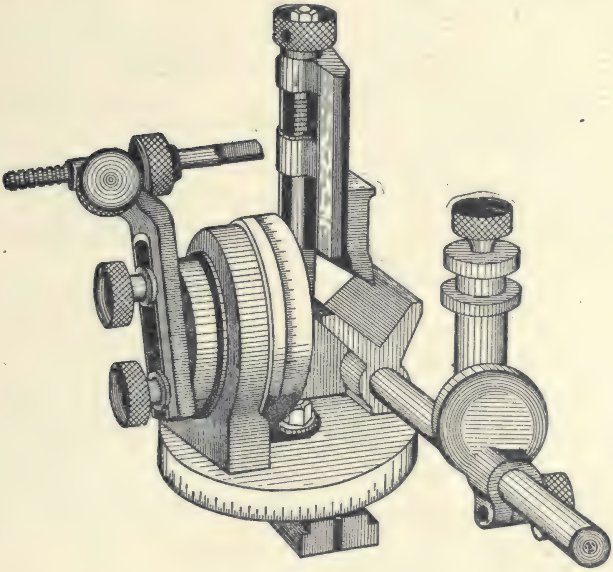


Fig. 216.

Generally speaking, cutters of this description are necessarily of a diameter that makes it advisable to use inserted teeth as shown in Fig. 218. The body may be made of cast iron, having a taper hole and key way, and held in place on the arbor by a screw.

The teeth may be made of tool steel and hardened, or of self-hardening steel if the cutter is to be subjected to rough usage. In either case they may be fitted to the slots by grinding on a surface grinder, and held in place by taper bushings and screws as explained under "Milling Cutters with Inserted Teeth." The construction of the body may be readily understood from the sectional view given in Fig. 219. The letters A, B, and C represent the diameter of cutter, width of face, and number of taper of the hole respectively, while D represents the key way.

The following table gives the dimensions of Face Milling Cutters of different diameters.

FACE MILLING CUTTERS.

A	B	C
5½"	2 "	No. 10 Brown & Sharpe Taper.
6½"	2 "	" 12 " " " "
7½"	2 "	" 12 " " " "
8½"	2⅜"	" 12 " " " "
9½"	2⅜"	" 12 " " " "

After boring and reaming the taper hole, the body of the cutter may be placed on a taper mandrel fitting the hole, and the ends and circumference finished to size. It should then be placed in the vise on the shaper or planer at the proper angle and the spline slot cut of an equal depth at each end of the taper hole. After removing the burrs it should be placed between the centers on the milling machine, and the slots cut for the teeth.

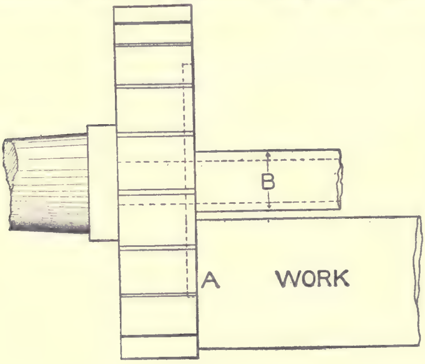


Fig. 217.

When the teeth are firmly secured in their proper places, they may be ground for clearance; the same general instructions given for grinding other forms of milling machine apply to this form.

Arbors For Face Milling Cutters. In. Fig. 220 is shown an arbor to be used in connection with *face* milling cutters. The shank A fits the hole in the spindle of the milling machine. B is the body which fits the taper hole in the cutter; this portion of the arbor has a spline which fits a spline slot in the cutter. A screw C enters the body of the arbor and is used in holding the cutter on the arbor. D is a nut used to force the cutter off the arbor when it is necessary.

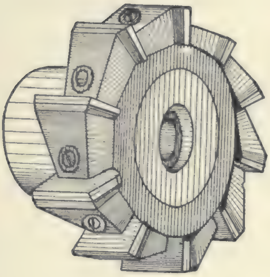


Fig. 218.

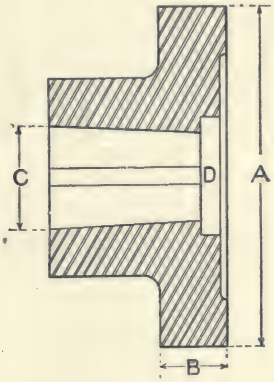


Fig. 219.

Stock used in making an arbor for a face milling cutter should be strong and stiff, and on this account tool steel is generally used. After squaring the end and roughing out the circumference, one end should be run in the steady rest and the screw hole in the end drilled and tapped, after which it should be countersunk at the end to furnish a center for use in turning and finishing. The tenon should now be turned to size and milled to thickness. If necessary to harden the end of the tenon it should be done before finish turning the arbor to prevent springing when heating. After turning the taper to fit the hole in the milling

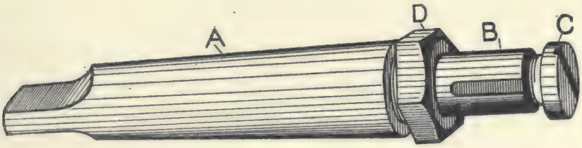


Fig. 220.

machine spindle, and on the opposite end to fit the cutter, the thread may be cut for the nut D, Fig. 220, after which the arbor may be cut for the spline as already explained.

The result will be more satisfactory if the two tapers are left a trifle large until after cutting the spline cut and are then ground to fit. Although the spline is intended to fit snugly in the slot in the arbor, the fit should not require pressure enough to endanger the truth of the arbor when it is pressed to position.

DRILL JIGS.

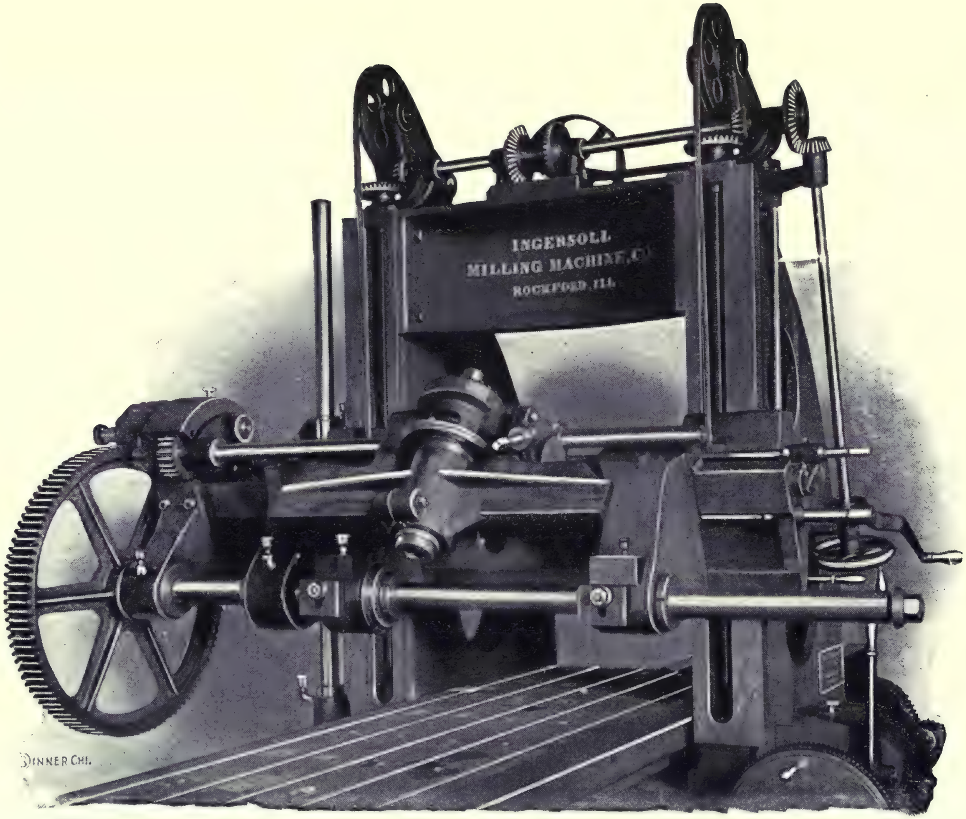
A drill jig is a device for holding work so that one or more holes may be accurately drilled; the locations of the holes may be governed by hardened bushings (guides) through which the drills run.

The design of a jig depends entirely on the shape of the piece and the nature of the work to be done. Jigs should be so designed that work may be placed in and taken out of them as quickly as possible. The fastening device should allow rapid manipulation, yet be capable of holding the work without danger of a change of location.

The construction of drill jigs calls for as great accuracy as any branch of the tool-maker's business; but no undue accuracy should be indulged in. If the location of a hole is near enough when within a limit of variation of $\frac{1}{16}$ inch it is a waste of time to attempt to get it within .0005 inch. Yet if the work is of such character that it is necessary that the holes be within a limit of variation of .0001 inch or even closer, every effort should be made to locate the drill bushings as accurately as possible.

While the design of the jig and the character of the work to be drilled must necessarily determine the method of construction, a few general points may not be amiss. The amount of *finish* given the exposed surfaces of a jig must be determined by the custom or requirements of the individual shop. In many shops it is not considered necessary nor advisable to finish the surfaces any more than to allow of their being wiped without the waste sticking to the jig.

A jig should be constructed so that it may be easily cleaned. Chips or dirt between the piece of work and the seating surface,



SWINGING VERTICAL ATTACHMENT FOR MILLING MACHINE.

or between the work and the stops, or locating points, throw the work out of true. As a result the holes will be at a wrong angle to the working surface, or they will be improperly located. Either condition would make the pieces unfit for use on most work, consequently bearing surfaces (wherever possible) should be cut away leaving several small seating surfaces, rather than one large one. A, Fig. 221, shows a piece of work resting on its entire seating surface; while B shows a surface cut away to leave six bearing points. If the seating surface is to be cut away as described, the raised portions should be so located that the article cannot be sprung by the action of the cutting tools or from any pressure that may be applied by any fastening device; otherwise the work will be thrown out of true as badly as though chips were lodged between the work and the seating.

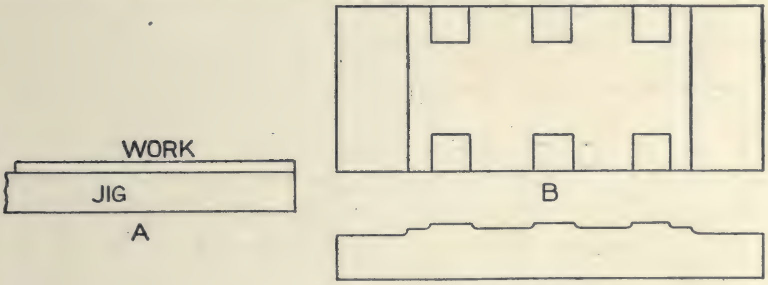


Fig. 221.

It is advisable, whenever possible, to divide a long, locating bearing into several short surfaces, thus decreasing the chance of holes becoming inaccurately located. When making jigs for pieces that are likely to have burrs at any given point, it is well to cut a depression in the seating or locating surfaces for the burr to set in, thus preventing the work being incorrectly located.

Seating surfaces should be made smooth so that chips and dirt may not stick to them, but they should not be polished nor finished as this would necessitate unnecessary cost and might cause the surface to get out of true.

A jig must be handled by the workman, and a clumsy jig cannot be handled as readily as one designed so that the workman can use it to advantage.

Sharp corners should be avoided wherever possible, and all handles or similar devices should fit the hand. If not, the amount of work done will not be the maximum, as the operator cannot do as much work with a jig which tires the hand and wrist.

As already stated the accuracy with which a jig should be constructed depends entirely on the nature of the work to be done, yet it should be borne in mind that any inaccuracy must of necessity be duplicated in the work.

EXAMPLES OF JIGS.

A few designs of jigs will now be considered to show the general requirements and the methods of construction.

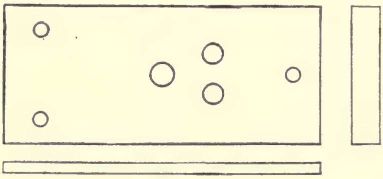


Fig. 222.

The slab jig, shown in Fig. 222, is the simplest form in use; it consists of a piece of flat stock of suitable thickness and of the same general outline of the piece of work to be drilled. The work may be clamped to the jig by means of U clamps, or parallel jaw clamps. If the jig is made of machinery steel the walls of the holes may be case-hardened by heating the jig red hot and sprinkling powdered cyanide of potassium around the hole, reheating in the fire and plunging in water; it should be worked back and forth in the bath so that the water will circulate through the holes. While this form of jig answers very well where but a few pieces are to be drilled, it is not suitable for permanent equipment on account of the wear of the holes. To overcome this, the holes may be made sufficiently large to receive hardened bushings having holes the size of the drill to be used. Fig. 223 shows this construction.

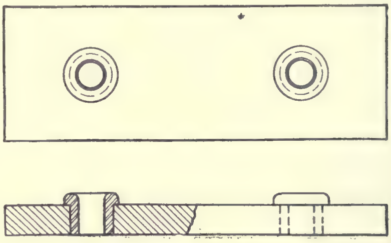


Fig. 223.

When holes are to be drilled at certain distances from one or more edges, it is necessary to have stops against which the work may rest. These stops may be pins, a shoulder, or a rib.

If the outline of the work has been finished by any process — as milling, punching or profiling — that insures uniform lengths and widths, the locating points may be placed on all sides of the piece as shown Fig. 224, in which pins are used as stops or locating points. It is necessary to flatten the pins on the sides that come in contact with the work to prevent wear.

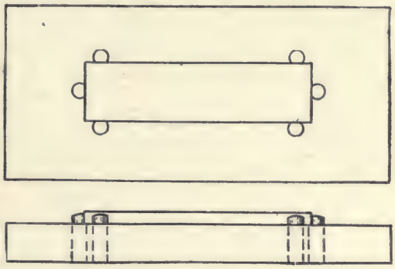


Fig. 224.

When a jig is to be used constantly, it is advisable to have a shoulder or rib for the work to rest against, rather than pins, as the former will not wear as rapidly. Fig. 225 shows the same form of jig as Fig. 224 except that ribs are substituted for pins.

When there is no surety that the dimensions of the different pieces are exactly alike it is advisable to locate the pieces in the jig from certain portions. The work must be forced against the locating points by means of a screw, cam or wedge. With a screw the work may be forced to position and held there even when the dimensions of the piece vary considerably. The cam is operated much more quickly than the screw and holds the work firmly when the size of the pieces vary but little. For certain purposes the wedge is an admirable holding device, but it is not generally used. Fig. 226 shows a jig in which the work is located from one side and end; the work being forced against the stops by means of a screw.

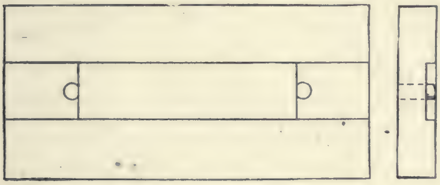


Fig. 225.

Fig. 227 represents the same jig having a cam instead of a screw.

When making any of these styles of jigs, the holes to contain the bushing may be located by several methods. If extremely accurate work is not necessary, a templet may be made, or a model piece used having the holes properly located; this piece may be placed in the jig and by means of drills the holes are transferred to the jig. If the bushings are to be used the holes may be enlarged by a counterbore having a pilot which fits the drilled hole and a body of the desired size of the bushing. While this method is cheap and good enough for certain classes of work, it is not advisable to use it for a very accurate job.

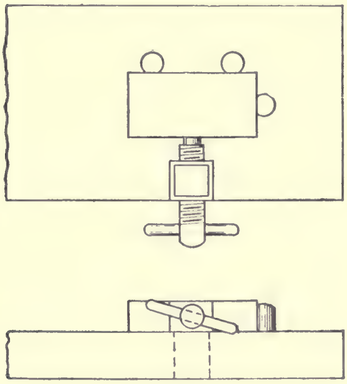


Fig. 226.

Another inexpensive method which insures *fair* results is to drill the holes as described above, then run a drill or reamer a trifle larger than the holes in the templet through the holes in the jig. Now place the templet in position and by means of a counterbore having a pilot which fits the hole in the templet counterbore the jig to the templet as shown in Fig. 228. Better results will be obtained if the ends of the teeth of the counterbore are made of the shape shown in Fig. 229, especially if the drilled hole should have run from its proper location.

A third method is used when the bushing holes must be located by measurement, or when there is no templet or model piece. By means of a surface gauge having the point of the needle set at the proper height from a scale attached to an angle iron, as shown in Fig. 230, scratch a dimension line on the surface which has been colored with blue vitriol. The needle is first set to the height of the locating rib. The scale attached to the angle

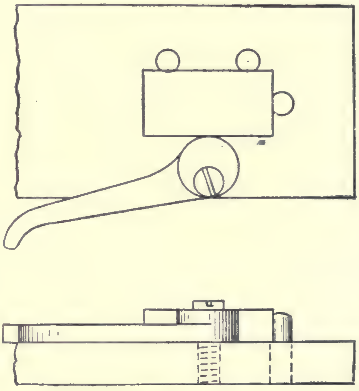


Fig. 227.

iron is adjusted so that the needle is at the exact height of one of the inch lines if possible, if not, at one of the half of quarter inch lines. The needle may then be raised to locate the center of the first hole and a line scratched while the jig is on edge. The centers of the other holes may now be laid off on this plane, after which the jig may be turned one quarter way around to locate the hole from the other measurements. Where the lines intersect prick punch the surface of the jig. For this work *do not* use the center punch made for centering work to be turned in the lathe. Use the prick punch which should be much lighter than the ordinary center punch; Fig. 231 shows the two punches. The point of the prick punch should be ground in some form of grinder in which it may be held and revolved in order that the point may be perfectly round. If this is not done it will be impossible to get the point of the center indicator to run true when attempting to true the jig on the face plate of the lathe.

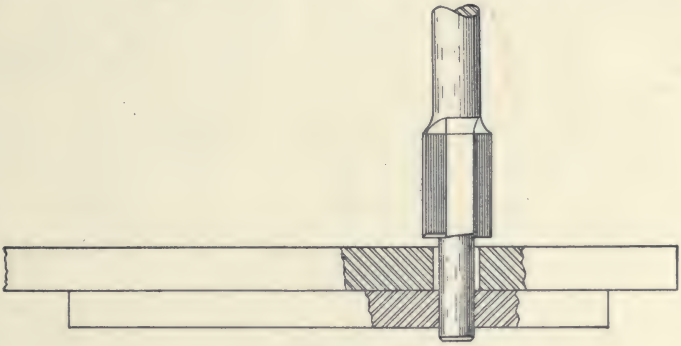


Fig. 228.

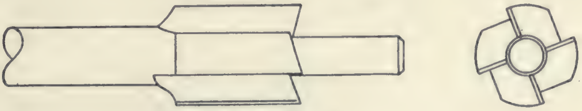


Fig. 229.

While the above method might be properly classed as an approximate measurement, an experienced workman can locate the bushings within a small limit of variation. More accurate work will result if the height gauge is used in laying off the dimension lines. The bottom surface of the extension is set to the height of the locating rib, as shown in Fig. 232; then by means of the vernier it may be raised to the exact height of the dimension desired, and the line scribed by means of the point of the extension.

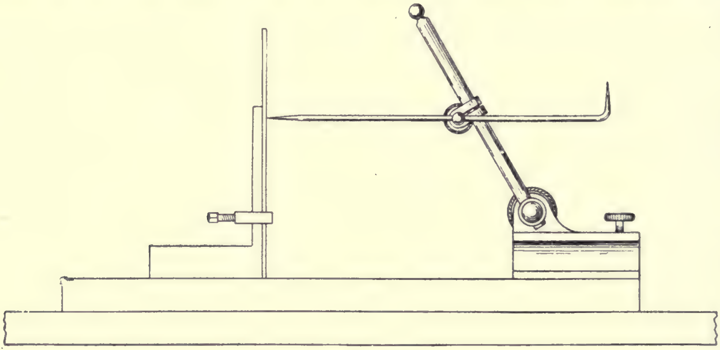


Fig. 230.

While this method insures greater accuracy in laying off dimension lines and is sufficiently accurate for most work, it is open to the objection that the tool maker may change the location of centers somewhat when prick punching.

When *precise* measurements are desired many tool makers determine the location of bushing holes by means of hardened discs or buttons. A very common size, Fig. 233, if $\frac{1}{2}$ inch diameter, $\frac{3}{16}$ inch thick and having $\frac{1}{4}$ inch hole. While it is not essential that the diameter be any particular size, it must be some fraction divisible by two without a remainder, as one half the size of the disc is considered in all computations. If the disc is .500

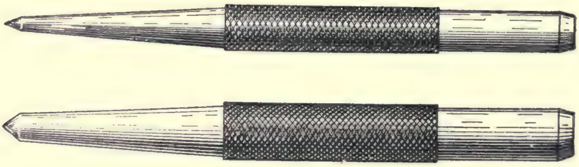


Fig. 231.

inch diameter, .250 inch is the decimal to be considered; but if the disc were $\frac{9}{16}$ (.5625) inch diameter it would be necessary to consider the decimal .28125 in all computations. In locating the disc most of the measurements are made with the vernier caliper, and as the tool is not graduated to read closer than .001 inch it would be impossible to consider the fractions of a thousandth of an inch; consequently discs .500 inch diameter are generally used.

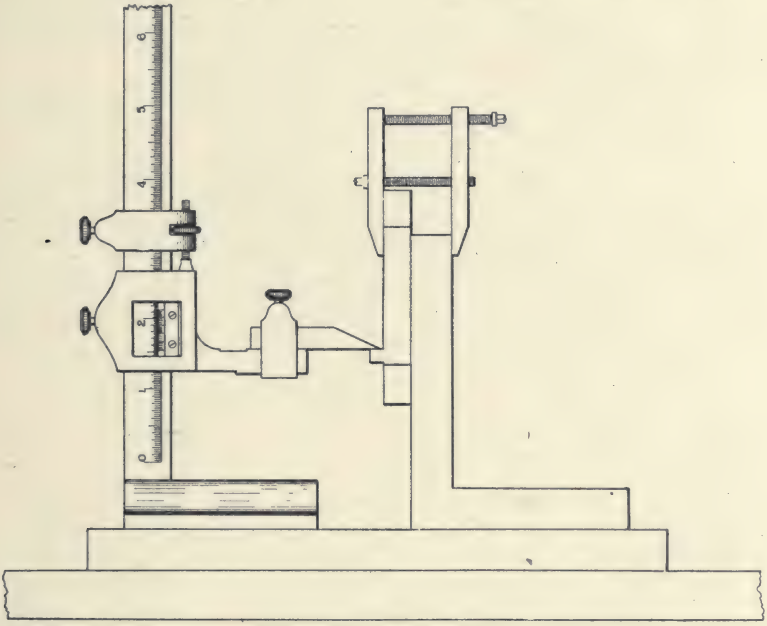


Fig. 232.

The locations of the different holes are laid off by means of the surface gauge, setting the needle to the scale fastened to an angle iron as already described. The holes are drilled and tapped for a screw somewhat smaller than the hole in the discs. The discs are now attached to the jig by means of screws. As the screws do not fill the holes in the discs, they may be moved until properly located. Fig. 234 shows a jig having the discs located in relation to the stops.

After properly locating a disc at each point where a bushing is desired, the jig may be fastened to the face plate of the lathe.

The jig must be so located on the face plate that one of the discs will run *perfectly* true. This may be determined by a test indicator operating on the outside of a button, as shown in Fig. 235. After locating so that the disc runs exactly true, the disc may be removed and the hole bored to the required size. The jig may now be moved to bring another disc to the proper location, after which it may be removed and the hole bored; this operation may be repeated until all the bushing holes are bored.

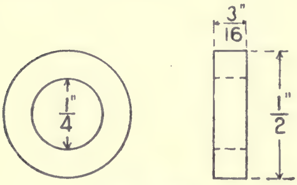


Fig. 233.

When jigs are made for permanent equipment, or if they are to be used constantly, it is well to provide some means of raising them from the drill press table to avoid inaccurate work occasioned by chips. When the jig is made of cast iron, the legs are sometimes cast solid with the jig as shown in Fig. 236. In order to grasp a jig handle in a manner that will not be tiresome to the wrist or hand, and allow sufficient room between the handle and the table of the drill press so that the fingers may not be cut by chips, the legs are made of a length that will raise the handle about $1\frac{1}{8}$ inches above the table. As cast-iron legs of this length would be too weak, it is customary to make the legs of tool steel hardening the ends that come in contact with the drill press table.

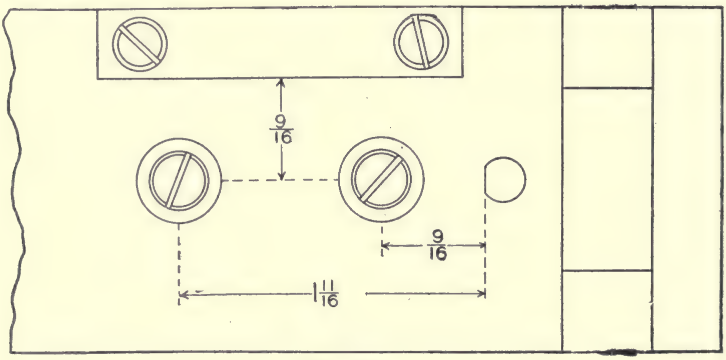


Fig. 234.

While the form of jig shown in Fig. 222 would give satisfaction on certain classes of work, the process of putting the work in, and taking it out of the jig would be very slow, as it would be necessary to clamp the work securely to resist the pressure of the cutting tools.

In order that work may be handled rapidly during these operations, jigs are designed so that the work will rest on the base of the jig as shown in Fig. 237. A leaf or cover containing the bushings can be raised when putting the work in place and taking it out.

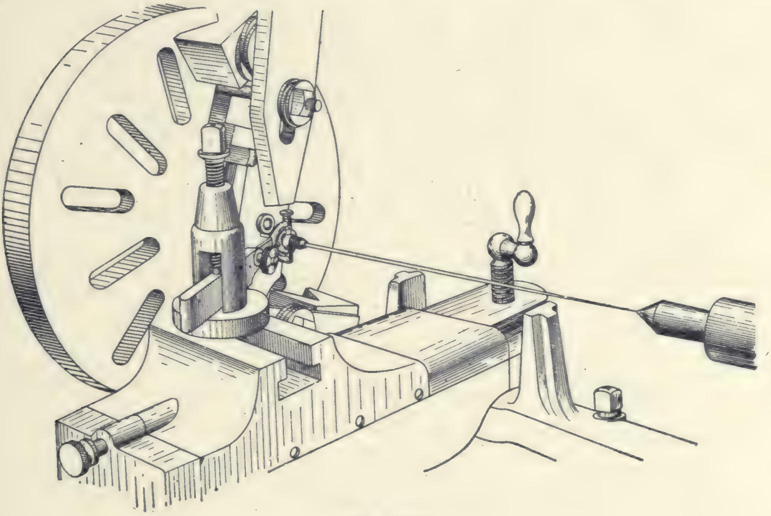


Fig. 235.

When the pieces to be drilled are of a uniform thickness the leaf may be made to rest on the piece. But should the pieces vary in thickness the leaf would not be parallel to the base; consequently the hole in the bushing would not be at right angles to the piece to be drilled. For this reason a little space is left between the top of the piece to be drilled and the bottom of the

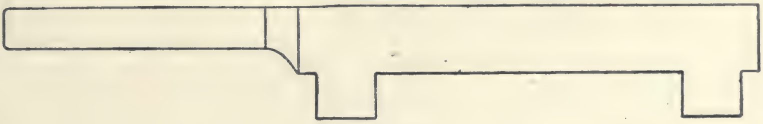


Fig. 236.

leaf, as shown in Fig. 238; a steady pin having a shoulder is located at the handle end of the jig. The upper end of pin may project into a hole in the leaf as shown thus relieving any strain on the joint of the jig occasioned by the action of the cutting tools.

When holes are to be drilled from opposite sides of a piece of work, as shown in Fig. 239, a jig may be constructed having legs on both upper and lower sides, but both sets of legs should be solid with the base as shown in Fig. 240.

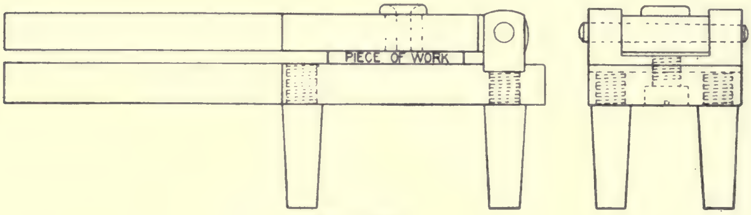


Fig. 237.

If the two end holes in Fig. 239 are of the same size and it is necessary to use a drill press having but two spindles, the legs on each side should be of a length that would make it possible to set the stops so that the drill would cut the required depth on each side. If a drill press having three or more spindles is to be used, the jig legs may be of a convenient length, as two drills of the same diameter can be used in two different spindles, each one to drill the required depth when the stop is set.

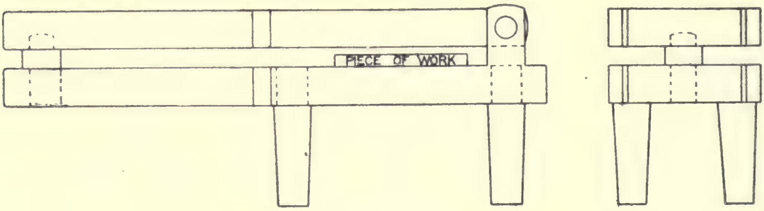


Fig. 328.

Drill jig legs are generally made of tool steel and are screwed into the base of the jig: the thread on the legs should be a good fit in the base. After screwing in place the ends of the legs should be machined to length by milling or planing; the legs may then be removed and the ends that come in contact with the drill press table hardened. The legs may now be polished (if that is allowable) and then screwed in place. The ends should now be ground to such a length that the surface where the work is seated will be of the correct height above the drill press table.

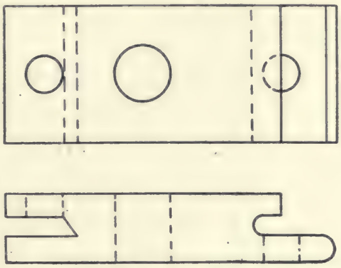


Fig. 239.

Grinding the ends of the legs can best be done in a surface grinder, or some form of universal grinder designed for surface grinding. After grinding, the ends of the legs may be lapped to remove any irregularity that may result from grinding. A very good lap may be made from a flat plate or block of cast iron. The surface to be used may be planed flat and smooth, then a series of grooves cut to form squares, as shown in Fig. 241. These grooves may be cut with a V-shaped tool and should be $\frac{1}{4}$ inch to $\frac{1}{64}$ inch

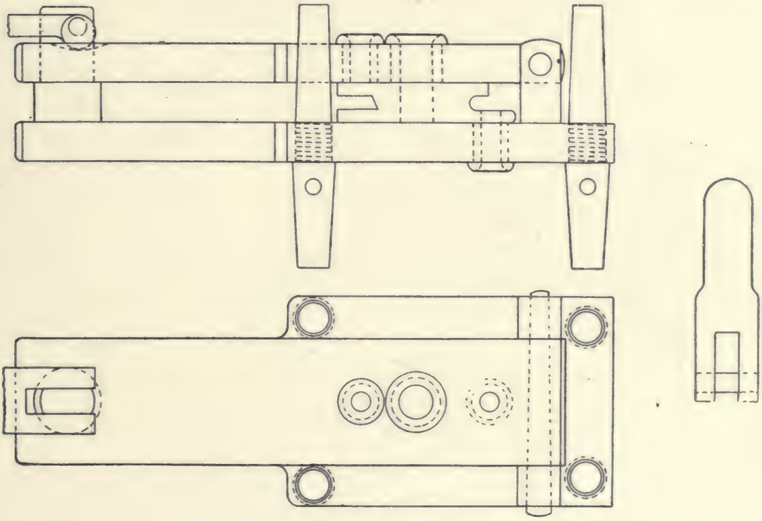


Fig. 240.

to $\frac{1}{32}$ inch deep. The grooves catch the emery and feed it to the work being lapped. If the pressure is not equal one leg may be cut shorter than the other, or may be lapped out of true, causing the jig to rock.

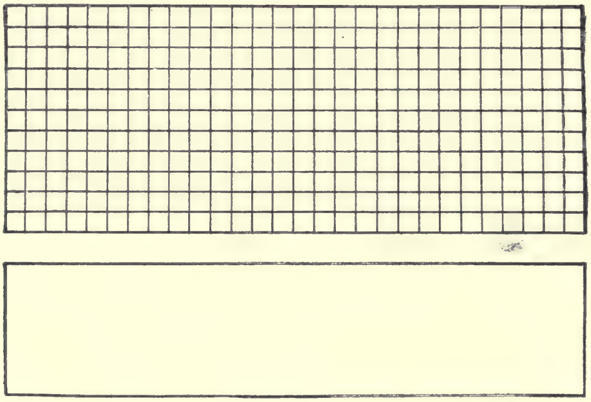
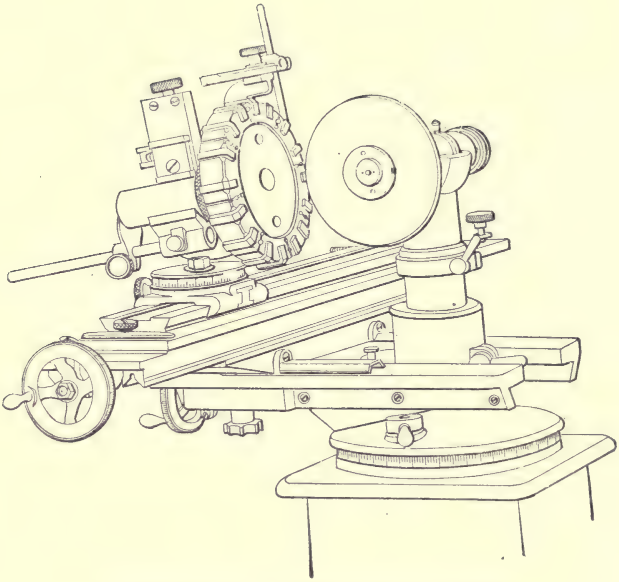
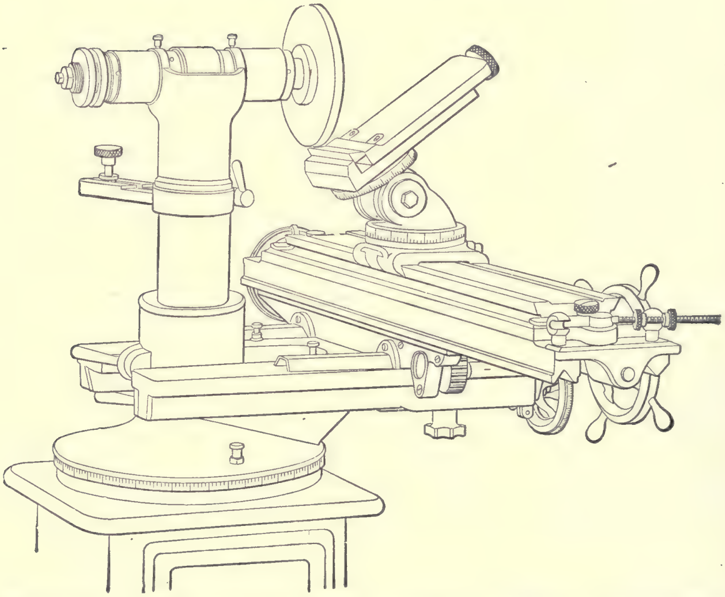


Fig. 241.



GRINDING A LARGE FACE CUTTER.



UNIVERSAL VISE ARRANGED FOR GRINDING BEVELLED SURFACES

Norton Emery Wheel Company.

TOOL MAKING.

PART III.

DRILL JIGS.

Fastening Devices. Various devices are used to fasten the leaf of a jig to hold the work in place or to clamp the leaf in position. The forms used depend upon the class of work being operated on.

If the leaf must be fastened solidly and the amount of time consumed is not of great importance, some form of screw clamp may be used. If, however, the work must be handled rapidly, the clamping device is generally operated by some form of a cam. However, a screw clamp may be designed to work quite rapidly.

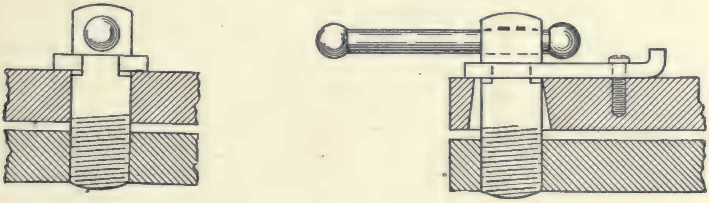


Fig. 242.

Fig. 242 shows a screw clamp which consists of a screw which has a hole drilled through it to receive a pin which is used as a lever to operate the screw. The screw is necked $\frac{1}{16}$ inch deep, the necking being $\frac{1}{8}$ inch wide; a flat washer is attached to the leaf of the jig by a small screw as shown. A slot of the width of the screw is cut in this washer in order to allow it to slide back and forth. In the end of the washer is a slot the width of the bottom of the necking in the screw. The other end of the washer is turned up as shown, in order to furnish a means of pushing back and forth. When the jig leaf is closed, the washer is pushed forward and the ends engage in the slot in the screw. One turn of the screw binds it very tightly. When the screw is given one turn to loosen it, the washer may be pushed back and the jig leaf raised.

If a quicker form of clamping is desired a cam may be used. The form represented in Fig. 240 is rapid and powerful.

Were it not necessary to use much power, but extreme rapidity of action is desired, a hinged cam lever of the design shown in Fig. 243 may be used. The cam lever is pivoted to the base of jig by means of a pin as shown. The lever passes into a slot in the leaf and the bearing surfaces on the under part of the head come in contact with the inclined surfaces at the end of the leaf.

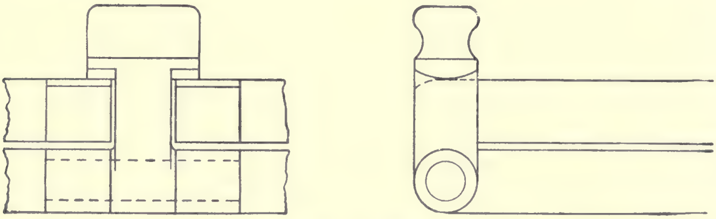


Fig. 243.

Bushings. Bushings of hardened tool steel are made for a permanent means of guiding the cutting tools. The hole in the bushing is made to fit the cutting tool that is to be guided. There are various forms of bushings; the plain straight form shown in Fig. 244 is sometimes used, but is objectionable because it may be pushed into the jig if the cutting tool is too large to pass through the hole.

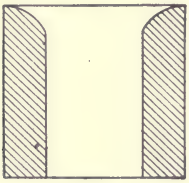


Fig. 244.

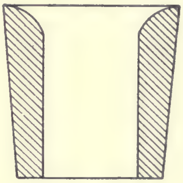


Fig. 245.

To overcome this tendency they are sometimes made **tapering** on the outside as shown in Fig. 245, but as this is an expensive form to make, and as it is an extremely difficult operation to bore the bushing hole in the jig, this form is not generally used for permanent bushings.

The most common form of bushing is straight with an enlarged portion or head. When no allowance is made for grinding on the outside it is commonly made of the form shown in Fig. 246. If the shoulder under the head is square, it is likely to crack at the sharp corner, or the head may be broken off when being forced in position. In order to avoid these difficulties a fillet is left under the head as shown in Fig. 247.

When it is essential that the location of the drilled hole or portion of the piece being machined in the jig be exact as to location, the tool must fit well in the bushing; and as the size and shape of the bushing is likely to change when hardening, it is advisable to leave enough stock to grind to size both inside and out. It is essential that the outside of the bushing be exactly concentric with the inside. After grinding and lapping the hole to size, the bushing may be placed on a mandrel which runs true and the outside ground to size. When machining a bushing which is to be ground on the outside it is necessary to neck in, under the head, as shown in Fig. 248, in order that the emery wheel may pass entirely over the part being ground and insure a straight surface. The under side of the head which rests on the upper surface of the jig should be ground in order that it may be true with the surface of the jig.

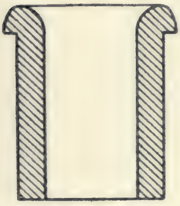


Fig. 246.

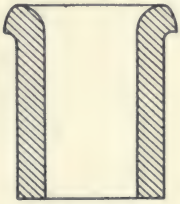


Fig. 247.

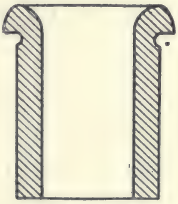


Fig. 248.

When grinding a bushing, a mandrel should be used which has been tested for truth. The mandrel should be straight or of very slight taper. If the taper is considerable, one end of the hole in the bushing, will not fit and the outside of the bushing will not be concentric with the hole. Consequently no matter how careful the tool maker might be in laying out his work and in boring the holes for the bushings the jig will not be accurate.

Size of Bushings. The outside diameter of a bushing is often determined by the design of the jig; for instance, two holes are often located so near each other that it is impossible to make the bushings much larger than the holes through them. Wherever possible the outside diameter should be made enough larger than the hole to leave a reasonably thick wall. A bushing with thin walls is likely to close in when being pressed to its seating; then again, if a cutting tool binds in a bushing with thin walls, the bushing becomes loose and turns in the jig.

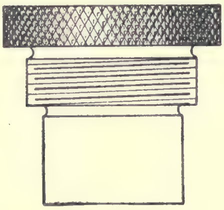


Fig. 249.

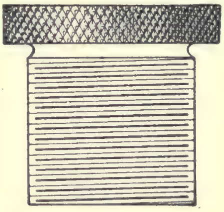


Fig. 250.

Removable Bushings. It is sometimes advisable to do two or more operations in the same jig. After drilling a hole it may be considered good practice to counterbore or tap it, or possibly it may be better to do the three operations while the work is seated in the jig. In such cases the bushing having a hole the size of the drill must be removed and one with a hole fitting the tool to be used inserted.

A very simple way of making a removable bushing consists in boring the hole in the jig large enough to receive a hardened bushing with a hole the size of the outside of the bushing to be used. If the hole in the large stationary bushing and the outside surface of the removable bushing are lapped smooth after grinding, they may be used for a long period before wearing enough to appreciably affect the location.

Tapered removable bushings are sometimes used; but on account of the expense of producing them and the fact that chips and dirt readily throw them out of their true locations, they are not very common.

Fig. 249 shows a form of removable bushing threaded on the outside to fit a threaded hole in the jig. If the thread on the outside of the bushing runs the entire length the process of screwing it in and out of the jig is necessarily very slow; consequently it is advisable to have but few threads. The balance of the length may be made to fit a bearing in the jig. If it is advisable to thread the entire length as shown in Fig. 250, the hole should be ground true with the thread to prevent change of shape in hardening. As it is not well to attempt to grind between the lands of the thread with the facilities in the ordinary machine shop, it is necessary to grind the hole true with the thread. This can be done satisfactorily by placing a piece of stock in a chuck on a lathe having a grinding attachment.

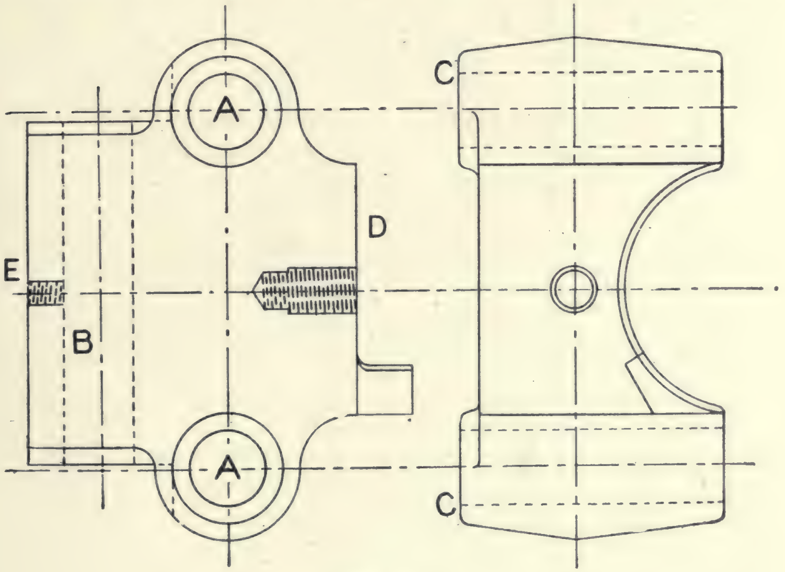


Fig. 251.

After drilling and boring the hole to tapping size, the thread may be chased so that the bushing is a good fit in the hole. It may then be screwed in and the hole ground to size.

If the piece of work is of a shape that makes it necessary to operate on all sides and the outline prevents the use of a clamp jig of the forms shown, a box jig must be used.

A Box Jig is made in the form of a box; the work is located in the jig by means of stops or locating points which differ according to the nature of the work. It is often advisable to design this form of jig so that all the holes in the work may be drilled at one setting; that is, if there are twenty holes in the piece, the jig is designed to allow drilling all the holes while the piece is in the jig. For other work it is advisable to make two or more jigs to drill the holes; this is the case when some part of the piece is to be machined after one or more holes are drilled but before drilling the others.

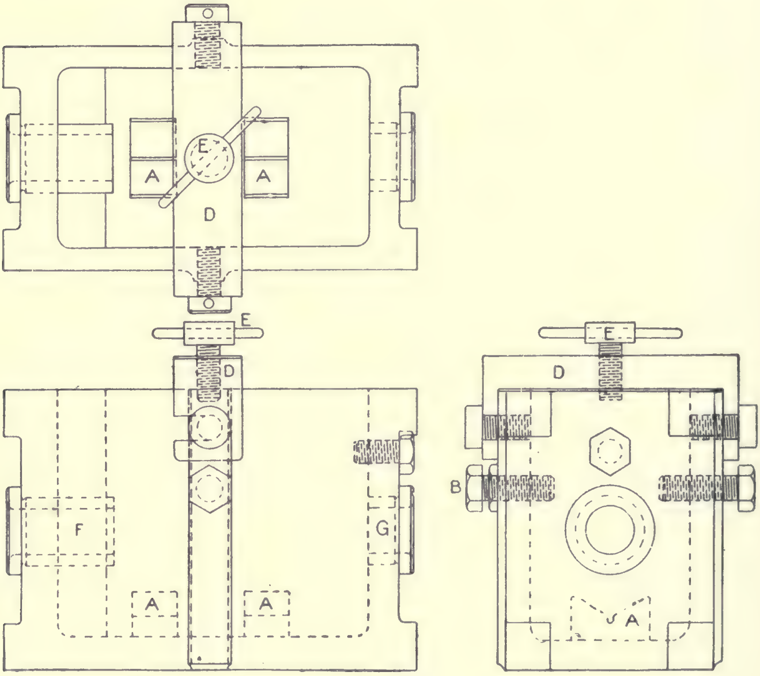
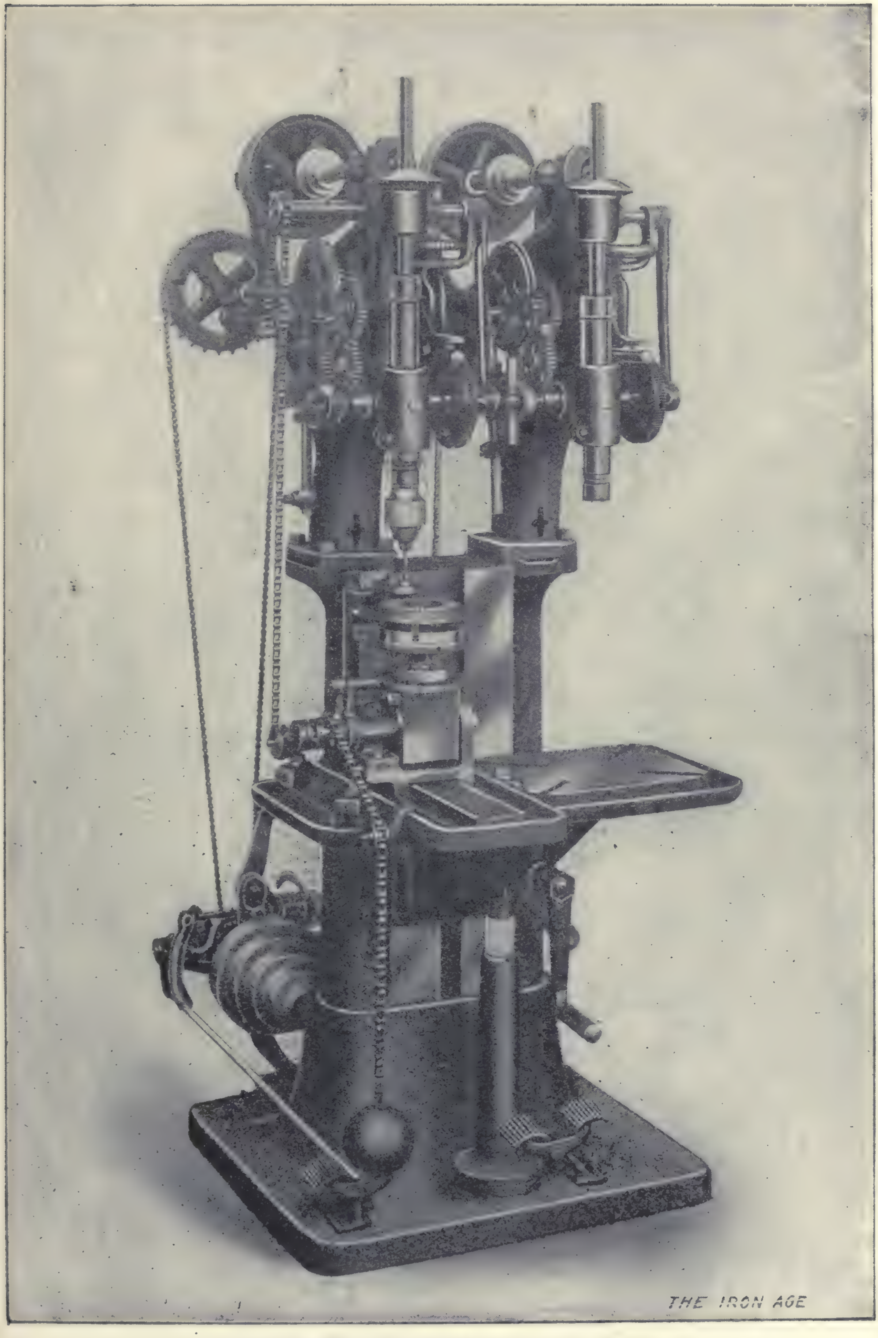


Fig. 252.

In Fig. 251 a piece of work is shown (three eighths size); through the piece it was necessary to drill three 1-inch holes as shown at A, A and B. As it was necessary to have the holes A A an *exact* distance from B it was found by experience that much better results could be obtained if the hole marked B was



TWO-SPINDLE AUTOMATIC DRILL
B. F. Barnes Co.

drilled and reamed in a jig, the piece taken out of the jig and the portions marked C and C milled in exact relation to the hole B and as nearly at right angles with the side of casting marked D as possible. After milling the portions C C, as described, the piece was placed in another jig locating it by the hole B and the surfaces C C; the holes A A were then drilled and reamed. In order to drill the hole B the jig shown in Fig. 252 was used.

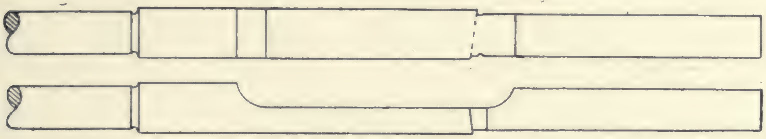


Fig. 253.

The piece was placed in the jig with the rounded surface E resting in two V blocks as shown at A. It was located by means of the fixed stop screw B and forced against A by the screw; it was held in position by the screw E which was located in the strap D. This strap was removed when putting a piece of work in the jig, or taking it out. As it was necessary to have the hole straight and true with the locating points, it was reamed with a single lip reamer having a pilot as shown in Fig. 253. The hole was drilled somewhat smaller than finish size ($\frac{1}{64}$ inch); the reamer was entered in the hole, the pilot fitting the bushing G. While the body of the reamer fits the bushing F, as previously explained, the single lip reamer acts on the same principles as a boring tool used in the engine lathe; the result being a hole straight and true. As it is necessary to have the hole in the upper bushing of the size of the body of the reamer, and as a drill $\frac{1}{64}$ inch smaller than this size must be used in drilling the hole, it was advisable, in order to properly start the drill, to use a trans-

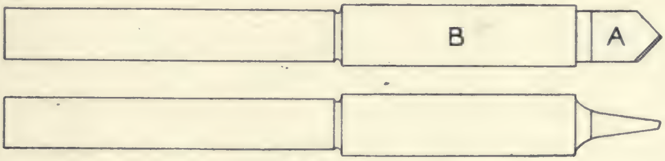


Fig. 254.

fer drill shown in Fig. 254, the cutting portion A of drill being the size of the drill to be used in drilling the hole, while B fits the hole in the bushing. By means of this drill a hole the size of the drill to be used was started in the casting perfectly true with the hole in the bushing yet somewhat smaller. When the hole had been drilled to a depth of $\frac{3}{16}$ or $\frac{1}{4}$ inch, the transfer drill wss removed and a twist drill of the proper size used to finish the drilling. When the piece of work was taken from the jig the portions marked C C, Fig. 251, were milled as explained. The piece was then placed in another jig, a pin which fits the reamed hole passed through the locating bushings and through the hole; by this means it was located to properly drill the other two holes. The second jig so closely resembles the first it is unnecessary to illustrate it.

PUNCH AND DIE WORK.

THE DIE.

A die used for punching a blank from a sheet of metal is termed a blanking die, and is generally considered as belonging to one of three classes: plain (or simple) die, gang die or compound die.

A set of blanking dies consists of a male die or *punch* and a female die or *die block.* The die block is that part of the die which has a hole of the same outline as the desired blank; the male die, or punch, is of a shape that fits the impression, or hole, of the die block.

When punching work on a punching press, the stock is placed on the die and the punch forced through it into the die; this drives a piece of stock of the same outline as the hole down into the die block. Now as the punch is forced through, the metal in the sheet closes on the punch and is raised by it. In order to prevent this the die block is provided with a *stripper plate* (or stripper). The stripper is fastened to the die or to a shoe holding the die at a height that allows the metal to be punched to pass freely between it and the die. The stripper must be strong enough to force the stock from the punch without springing, especially if the punch is slender and the stock thick, because under these conditions the punch would be sprung or broken.

In order to guide the stock over the die and leave the proper amount of margin or scrap at the edge of the sheet, a *guide* is furnished. The guide is usually made of stock sufficiently thick to bring the stripper the proper height above the face of the die.

A *gauge pin* (or stop) is usually provided; this pin is located so that the proper amount of scrap is left.

In Fig. 255, A is the die block, B the hole through the die block of the shape of the piece to be punched, C the stripper, D the guide and E the gauge pin or stop.

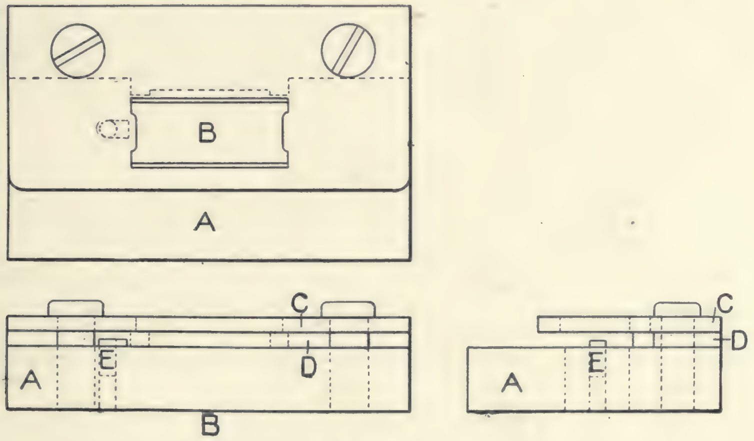


Fig. 255.

Dies are held in position on the punching press bed by various methods, the most common of which is by means of the forms of hold-fast shown in Figs. 256 and 257. These die holders are known by various names, such as chair, bolster, chuck and die holder. Large dies are clamped to the bed of the press.

Dies are usually beveled on the edges that come in contact with the die holder to prevent their rising from the seat. The angle given to the edges varies according to the ideas of the designer. An angle of 10° from the vertical gives satisfaction, although some mechanics insist on an angle of 15° or even 20°.

Fig. 258 shows a die, whose edges are at an angle of 10°, in a die holder; the die being held in place by set screws. It is generally considered advisable to place a gib between the set screws and die as shown. Sometimes the gib is omitted, the set screws bearing directly on the edge of the die. Some tool makers prefer a die holder without set screws, the die being held in place by the gib which is made wedge-shaped and is driven to place, thus securely holding the die.

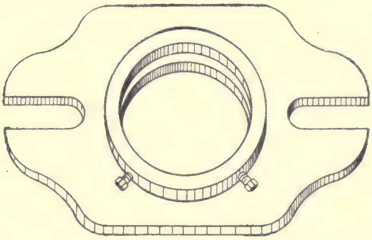


Fig. 256.

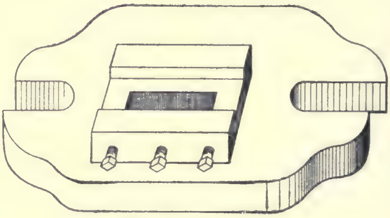


Fig. 257.

Fig. 259 shows a method of holding dies which allows the die to be easily set in position when rigging up. The die may be placed on the seating of the die holder and brought to the proper location; the set screws may then be brought against the edge of the die, or against strips of steel which may be placed between the edges of the die and the set screws.

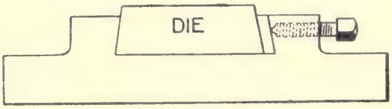


Fig. 258.

When making several dies of equal width and thickness a good method is to plane the two sides of a bar to remove the outer surface, then bevel the edges to the required angle. Pieces may then be cut off to any required length as wanted.

The upper surface of the die may be finished smooth by planing with a smoothing tool; it may be ground in a surface grinder, or it may be finished with a file. It is necessary to have the surface smooth in order to lay out the correct shape of hole, as it cannot be laid out correctly or distinctly on a roughly machined surface.

The face, or upper surface of the die is now covered with blue vitriol solution and the outline of the piece to be punched laid out. A die should be laid out in such a manner that the stock to be punched may be readily fed to the die. The *grain* of the stock should run in the proper direction if the product is to be a tempered spring or any article where the grain of the stock must be considered.

After the die has been carefully laid out from a templet, or drawing, all round corners should be drilled with a drill of the proper size, and reamed from the back side of the die with a taper reamer to give the desired clearance; the balance of the stock is removed by drilling, as shown in Fig. 260. The method of removing the center, or core, depends on the custom practiced by the individual die maker; one may drill the holes so that they break into one another. When this method is adopted it is advisable to use a straightway (straight fluted) drill. Another will drill small holes and use a counterbore to enlarge to size; the counterbored holes breaking into each other.

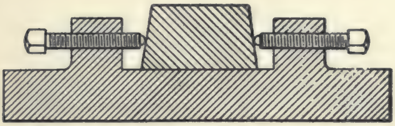


Fig. 259.

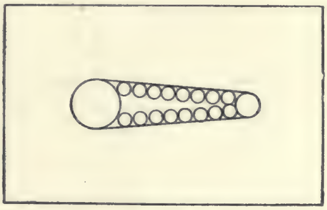


Fig. 260.

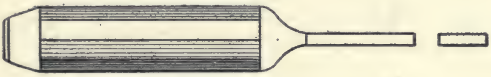


Fig. 261.

Usually the holes are drilled with at least $\frac{1}{64}$ inch to $\frac{1}{32}$ inch between them, and then the intervening stock is cut out with a flat-ended "hand broach." Fig. 261 shows a tool of this description.

Generally speaking, the last mentioned method is the safest and quickest. After removing the center, the die may be placed in a die milling machine or a die sinking machine, and by using a milling cutter of the proper taper, the desired angle of clearance may be given; the amount of clearance varies with the nature of the work to be done.

When a die is milled on a die milling machine of the form shown in Fig. 262, the cutter spindle is underneath the die, the face of which is uppermost, consequently the milling cutter can be made largest at the shank end of cutting part, the required taper being given as shown in Fig. 263. If the outline of the hole is milled on a die sinking machine, it is necessary to use a cutter of the shape shown in Fig. 264 in order that the face of the die having the lines will be uppermost. After working the impression as near to shape as possible by milling, it can be finished by filing. In order to give the die the proper clearance the walls may be gauged with a bevel gauge of the form shown in Fig. 8. As the amount of clearance differs in various shops, and on different classes of work, no stated amount can be given for all cases; the amount varies from $\frac{1}{4}$° to 3°. The latter is excessive and is seldom given unless it is necessary that the piece punched drop from the die each time.

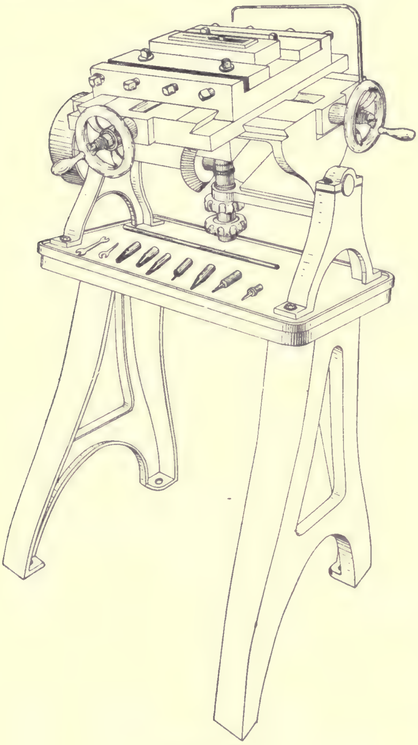


Fig. 262.

If the die is milled as described above it will be necessary to work all corners to shape with a file. If a universal milling machine having a slotting attachment is used, the corners can be properly shaped and the necessary clearance given by using suitably shpaed cutting tools, and turning the fixture to the proper angle.

Fig. 265 shows a slotting fixture attached to a universal milling machine, while Fig. 266 shows a fixture known as a die shaper which is also attached to a milling machine.

Die blocks have their cutting edges beveled in order that the blank may be cut from the stock by a shearing cut. *Shear* is given the face of the die to reduce the power necessary to cut the blank from the stock ; thus enabling a press to punch a blank from thicker stock. It also reduces the strain on the punch and die.

The face of the *die* is sheared when the blank, or piece forced through, is the product to be saved. But if the piece surrounding the blank is to be saved, and the blank is of no use, the face of the die is left perfectly flat and the end of the *punch* is sheared.

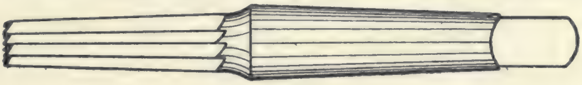


Fig. 263.

The cutting face of the die may be sheared by milling or planing to the desired angle which depends on the thickness of the stock to be punched and also the power of the press. A common method of shearing a die is shown in Fig. 267, which shows a section of a die used for punching a heavy spring. The end of the *punch* is left flat. The punching commencing at the center A, is continued with a gradual shearing cut as the punch descends until it reaches the ends BB, of the opening. The blank punched will be straight while the stock will bend somewhat unless it is quite stiff, in which case it springs back to shape when the pressure is removed.

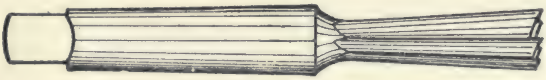


Fig. 264.

When the punching requires an amount of power in excess of the capacity of the press, as in the case of the forging shown in Fig. 268, it is necessary to trim the flash occasioned by the process of drop forging, and at the same time punch the end to shape as shown in Fig. 269. It is obvious that the material removed is of no value as a product, and as it is necessary to use a light press, the die may be given a shear as shown in Fig. 270 ; thus making it possible to do the punching on a press whose capacity is not equal to the job if the die had been sheared as shown in Fig. 267.

In order to facilitate the operation of grinding the face of a die, it is frequently made with a raised boss around the hole as shown in Fig. 271.

Sectional Dies. In order to make it easier to work dies to shape, they are sometimes made in two or more pieces; these are fastened together when in use. In the case of a plain die of the form shown in Fig. 272, the die is made in two pieces which are held in their relative positions by the dowel pin at each end as shown at A and B. When in the die holder they are held together in such a manner that they cannot spread. Dies of this form should have the surfaces that go together finished true; the pieces should then be clamped together and the dowel-pin holes drilled and reamed. They should then be taken apart and any burrs caused by drilling and reaming removed. The pins should now be inserted and the top and bottom of the die planed. The outlines of the piece to be punched may now be laid out and the round hole at one end drilled; after which it should be reamed from the back with a taper reamer to give clearance. The die may now be taken apart, and the opening cut out on the planer or shaper; the sections of the die being held at the proper angle to give the desired amount of clearance. After placing the two pieces together the opening may be finished with a file and scraper to the templet.

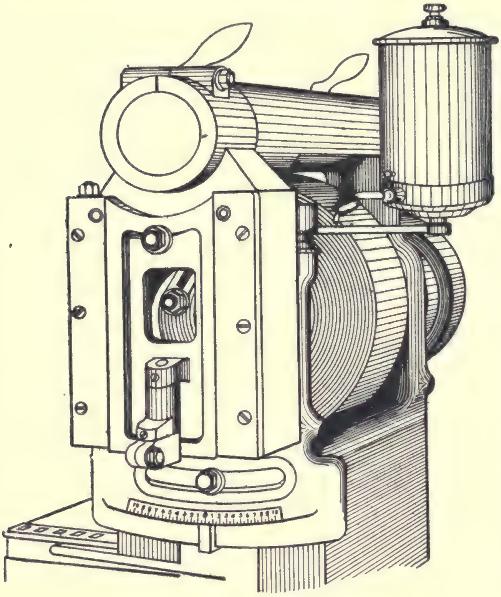


Fig. 265.

To hold the die together securely it is necessary to use a die holder of the form shown in Fig. 273. The die is represented in place in the holder which is held in the bolster which is in turn attached to the bed of the press. When the die is finished to the templet and the proper clearance given, make sure that the walls of the opening are straight (not crowning), although it is not always considered advisable to carry the clearance to the edge, as the size of the opening would then increase every time the die was sharpened. In such cases the clearance extends from the bottom to within a short distance (about $\frac{1}{8}$ inch) of the cutting surface as shown in the sectional view, Fig. 274. In this figure the clearance is exaggerated in order to illustrate the idea.

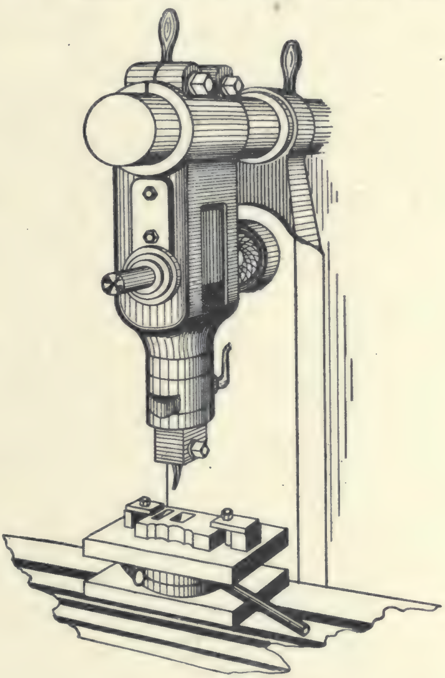


Fig. 266.

The walls of the upper part of the opening are at right angles to the base of the die, but they must be straight, that is, not crowning; because if the opening is wide enough to allow the punch to pass through the crowned part, the stock, if thin, would be likely to leave the blank with ragged edges which would extend up on the sides of the punch and have a tendency to burst the die.

Before hardening, the stripper and guide-screw holes should

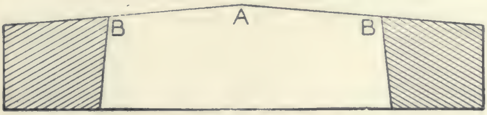


Fig. 267.

be drilled and tapped and the hole drilled for the gauge pin, or stop. If the name of the part to be punched, or the shelf number of the die are to be stamped it may be done now. After all screw holes, stop-pin holes, etc. are filled with fire clay mixed with water to the consistency of dough, the die is ready for hardening. Extreme care should be exercised when heating a die for hardening: it should be no hotter than is necessary to accomplish the desired result, and the heat should be uniform throughout; the corners must be no hotter than the middle of the piece and the outside surface must be of the same temperature as the interior of the steel. The water in the bath should be slightly warmed to prevent any tendency to crack. The die should be lowered into the bath and swung back and forth gently so that the bath may pass through the opening, and harden the walls. As soon as the "singing" ceases it may be removed and plunged into a tank of oil and allowed to remain until cold. It may then be brightened and the temper drawn. If more than a few minutes is to intervene between the time the die becomes cold, and commencing to draw the temper, it should be held over a fire or placed where it can be heated to remove the internal strains which have a tendency to crack the piece.

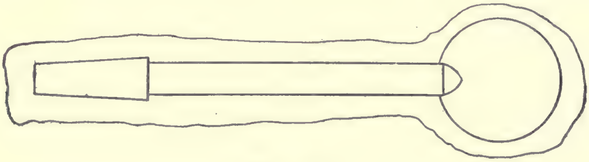


Fig. 268.

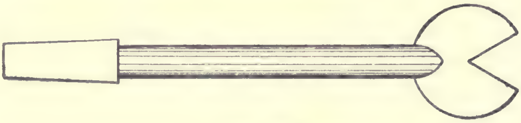


Fig. 269.

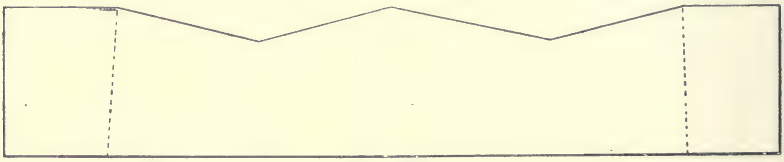
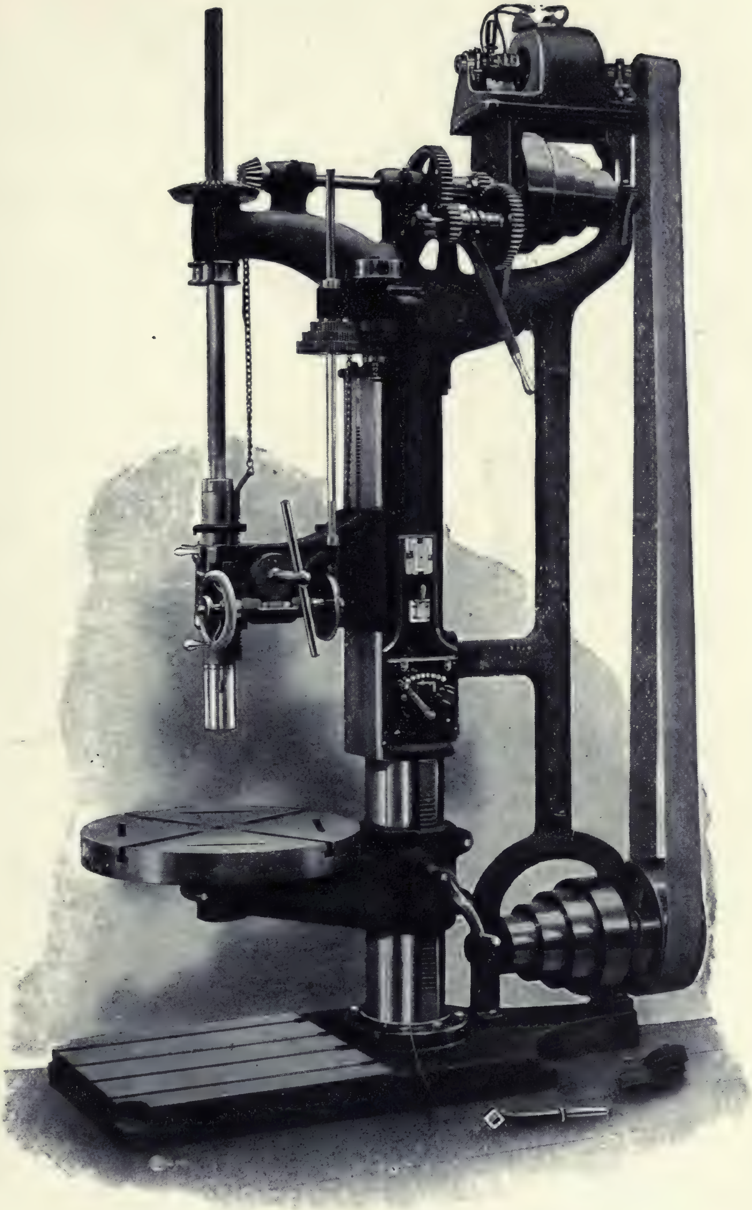


Fig. 270.

A very common method of drawing the temper of dies and similar pieces, is to heat a piece of iron to a red heat and place the



MOTOR-DRIVEN DRILL.
The Hamilton Machine Tool Co

hardened piece on it leaving the face of the piece uppermost. Experience has taught the writer, however, that this method of treatment is too harsh for hardened steel, especially if the job is in the hands of one not thoroughly experienced. One side of the piece is subjected to an intense heat while the opposite side is exposed to the cooling effects of the air. If an open fire is used a plate may be set on the fire, and the die placed on the plate before it is hot; now the temperature of the plate may be raised gradually, turning the die occasionally. In this manner the temper may be drawn to the desired degree with safety. When such a fire is not available two plates may be used, one heating while the other is in use. The first one should not be very hot, the next somewhat hotter, and so on until the die is drawn to the desired color.

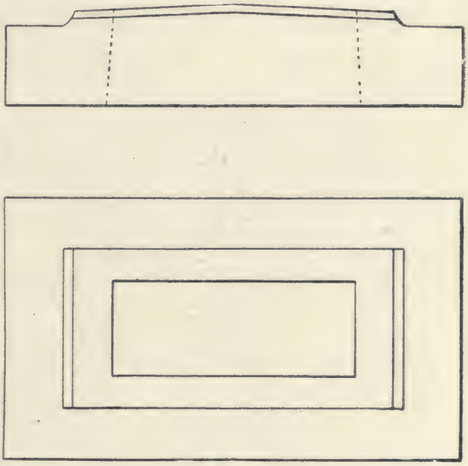


Fig. 271.

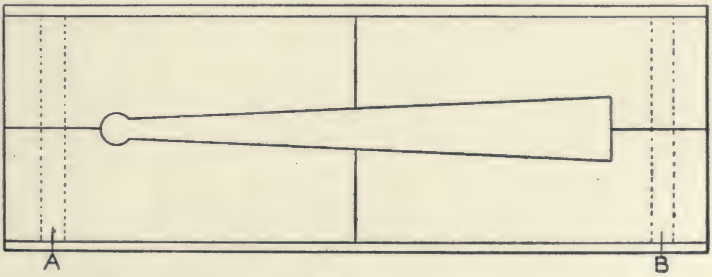


Fig. 272.

When a die of such a shape that is likely to give trouble, is to be hardened much more satisfactory results will follow if the "Pack Hardening" process is used. Run the dies from 1 to 5 hours in the fire after they are red hot, then dip in raw linseed oil.

THE PUNCH.

The punch is used to force the metal through the die thus producing pieces of the desired shape.

In the case of small plain dies the punch is generally made of the form shown in Fig. 275. The end A is of the same outline as the opening in the die, the shoulder B which bears against the shoulder of the punch holder takes the thrust when the punch is working. The shank fits the hole in the punch holder, or in the ram of the press.

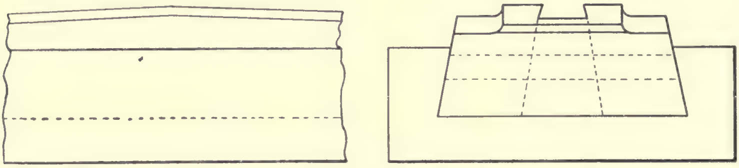


Fig. 273.

It is customary in most shops in this country to make the die to a drawing, or templet, and then harden it; after which the punch is fitted to it.

In the case of a punch for a plain die, the templet may be used in laying out the punch. If the shape of the opening in the die is the same on each side as shown in Fig. 276 and the die does not change shape in hardening the templet may be used either side next to the face of punch, but if the outline is of the form shown in Fig. 277, it will be necessary to exercise care when laying out the face of the punch from a templet, because the side of the templet placed against the face of the punch when laying it out will be opposite the one that would be placed against the face of the die when laying *that* out.

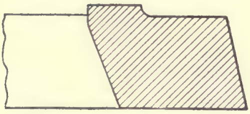


Fig. 274.

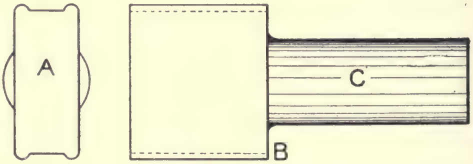


Fig. 275.

In order to obviate this trouble many tool makers lay out the face of the punch from the opening in the die before beveling the face for shear. In order to hold the punch and die together so that there will be no danger of the punch slipping while the required shape is being transferred, a die clamp of the form shown in Fig. 278 should be used.

The punch blank should be machined on both ends and the shank turned to size; the end which is to fit into the opening in the die should be finished with a smooth flat surface which should be colored with blue vitriol. After coloring, it may be clamped to the face of the die by means of the die clamp and the outline of the punch marked on the face by scribing through the opening in the die. This outline should be accurately marked with a sharp pointed prick punch as the scribed line is likely to become obliterated by the various operations of machining the punch to shape.

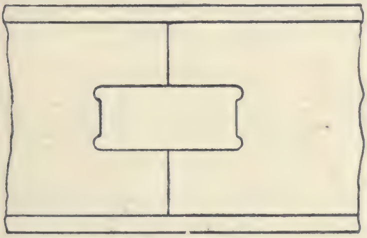


Fig. 276.

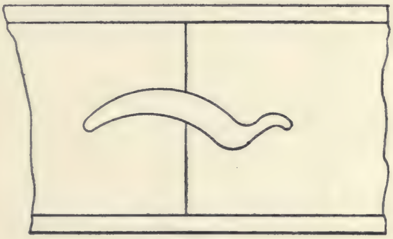


Fig. 277.

After the outline has been carefully prick punched, the punch may be milled or planed to shape leaving stock enough at all points to fit the die. If the die is to be beveled for shear, it should now be done and then hardened before fitting the punch.

The punch should be machined close to the lines and then placed over the hardened die and forced into it a little (about $\frac{1}{16}$ inch). This is termed "shearing in," and is the custom generally employed in this country.

After the punch has been sheared in for a short distance it may be removed and worked to size by means of chisel, file and scraper to the "witness" mark as the portion sheared in is termed, the operation of shearing may be repeated until the punch enters the entire length.

Fit of Punch and Die. If the material to be punched is thin or soft, it is necessary to make the punch a closer fit in the die than if the stock is heavy or very stiff. Thin stock requires a punch nicely fitted to the die in order to avoid ragged edges on the punched blank. When punching stock $\frac{1}{8}$ inch in thickness, the punch may be $\frac{1}{64}$ inch smaller than the die; if the stock to be punched is very stiff there may be a greater difference, however, the exact amount depends on the nature of the material to be used and the character of the tool.

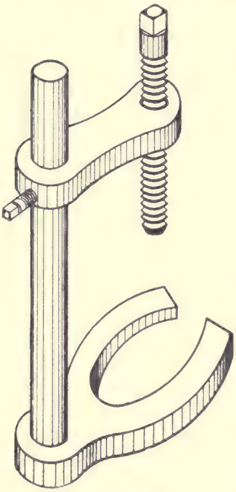


Fig. 278.

After the punch has been fitted to the die, the cutting end should be faced off to insure a good working surface and sharp edges. Any distinguishing names or marks necessary should be stamped on it, after which it is read for hardening.

Hardening the Punch. Punches are hardened by heating in a muffler furnace, or in a clear charcoal fire, to a *low red* and cooling in water or brine, preferably the latter. Punches whose form insures strength need be hardened only on the end; the hardening should not extend quite back to the shoulder or shank. Small, slender punches are sometimes hardened the *entire* length, especially if they are to punch stock nearly as thick as the diameter of the punch; in which case the punch would become upset when used, if it were not hard the entire length.

It is generally considered good practice to have the punch softer than the die; on this account the punch is generally drawn to a color that insures this result. If a die is drawn to a straw color, the punch is drawn until it assumes a distinct purple, or even a blue color.

The punch is sometimes left soft, not hardening it at all. When this is done, it can be upset, and refitted when worn. As this would not work satisfactorily in many cases, it can be advocated only when it would be considered advisable to use a *soft* punch.

It is sometimes necessary to punch a hole in a piece of work that has been machined to some given shape. The piece is placed on the face of the die against locating points, or in an opening in a gauge plate; the opening being of the same outline as the piece of work. In Fig. 279 is shown a blank intended for a gun-sight leaf; A shows the blank before the rectangular hole is punched, while B represents the leaf after punching. The hole is punched somewhat smaller than finished size, enough stock being left to work to size with broaches.

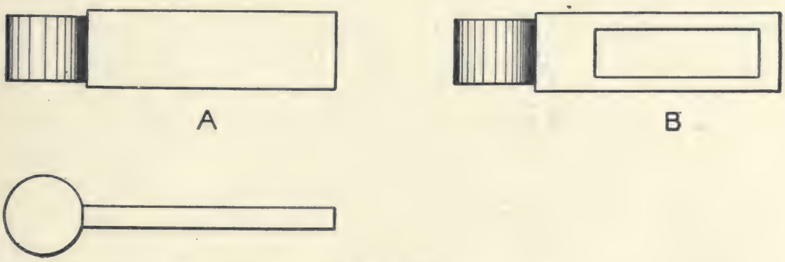


Fig. 279.

When punching work of this description, it is necessary to leave the face of the die flat; the punch is sheared as shown in Fig. 280. The piece punched from the leaf is of no value in this case, consequently the face of the punch is beveled, and the face of the die is left flat in order that the sight leaf may be straight after punching.

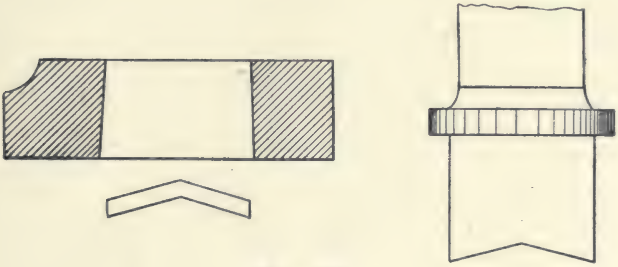


Fig. 280.

When a die and punch are to be used for an operation similar to the one described above, it is necessary to make a stripper of a form that allows the pieces to be easily placed in position and removed. As the piece which is punched is likely to increase in width from the operation, it is advisable to have stops or a guide on one side only in order to allow the piece to be readily removed after it is punched. Fig. 281 shows the same die with stripper and guide attached. The stripper is raised sufficiently from the die to allow the work to be readily inserted. A gauge pin is furnished for the end of the piece to determine the position of the slot in relation to the end. On one side is furnished a guide against which the piece rests to bring the slot central. The piece is held against the guide by means of a screw driver, a thin piece of steel, or a piece of wood.

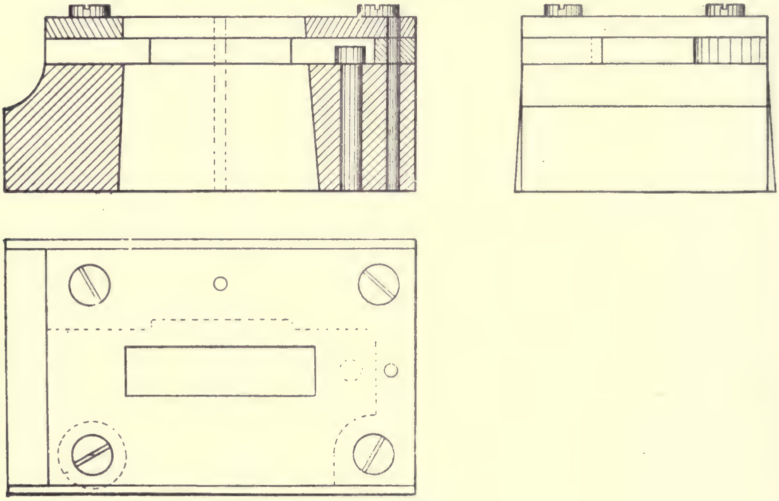


Fig. 281.

When a piece is to be punched and its size does not allow of a stripper being attached to the die as in the previous example, the stripper may be attached to the punch as shown in Fig. 282. It is made in such a manner that the stripper plate descending with the punch comes in contact with the piece being operated on and remains stationary. Between the stripper plate and the punch holder are coil springs which are compressed. The punches pass through and return. The stripper being forced downward by the action of the springs forces the blank from the punches. The gauge plate which is securely fastened to the die by means of screws and dowel pins as shown, has an opening of the same general outline as the blank but somewhat larger in order that the blank may be easily put in place and removed.

GANG DIE.

The gang die is used when punching a blank, together with any holes it is necessary to have in the blank, without being obliged to handle the pieces twice as would be the case if they were "blanked" at one operation and the holes punched at another. Two operations would be necessary if a punch and die of the form shown in Fig. 282 were used.

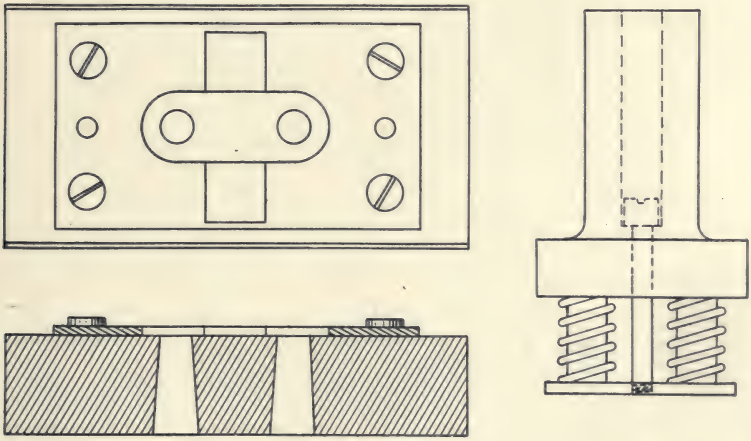


Fig. 282.

A common design of a gang die is shown in Fig. 283 which represents the piece operated on in Fig. 282. This die not only punches the holes but cuts the blank from the sheet. The stock is fed from right to left. The two holes are punched first and the stock is then fed along and the blank punched. At the same time the two holes are punched for the next blank to be cut. When the first two holes are punched in a strip of stock, the sheet is placed against the guide C, the end projecting slightly over the edge of the opening E. As the punches descend the holes F and F¹ are punched, and the end of the sheet is trimmed to length to stop at gauge pin D, which should be located about .010 inch farther to the left than the proper location for punching. The center pins as they enter the holes draw the stock back to the proper location. It is obvious that the punch A must be a trifle longer than the punches B¹ and B. Were the small punches longer than A or even of the same length they would hold the stock in such a manner that the centering pins could not locate it, and, again, the centering pins striking on one edge of the hole would spoil the blank punched and probably the pins would be broken. The centering pins must not be a tight fit in the holes or the punched blank will stick to the pins and return with the punch. By carefully fitting the pins to a punched hole they may be fitted close enough to insure punching within a very small limit of variation. In fact for most classes of work it is possible to punch near enough to standards for all practical purposes.

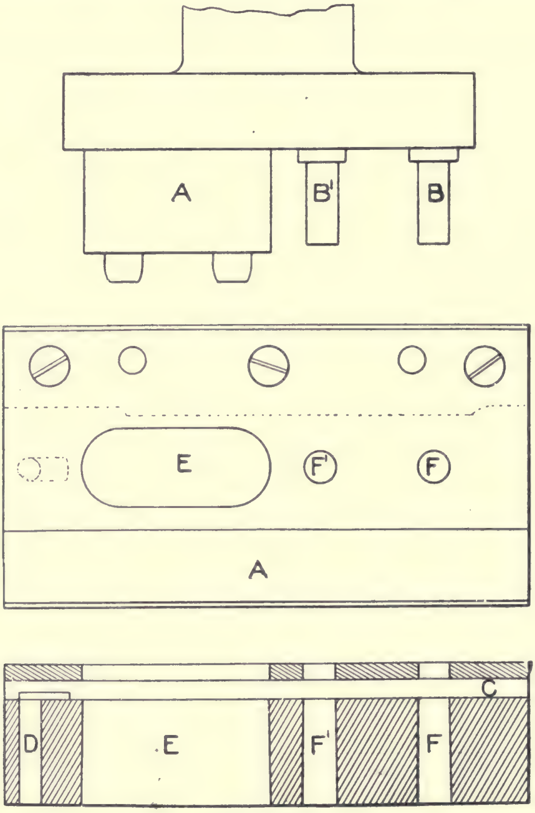


Fig. 283.

When punching work with gang dies of the design shown in Fig. 283, it is easily seen that in the case of work being punched from strips wider than is necessary to get out two punchings, the scrap left between must be removed by some means. This is frequently done by a large lever shear, or a pair of power shears; this is a costly operation where many pieces are punched at a time. To do away with this extra cost, dies are made having an extra opening and a punch working into this cuts away the surplus stock, or scrap, leaving the edge of the sheet straight and in condition to rest against the guide. In Fig. 284 the opening A is the

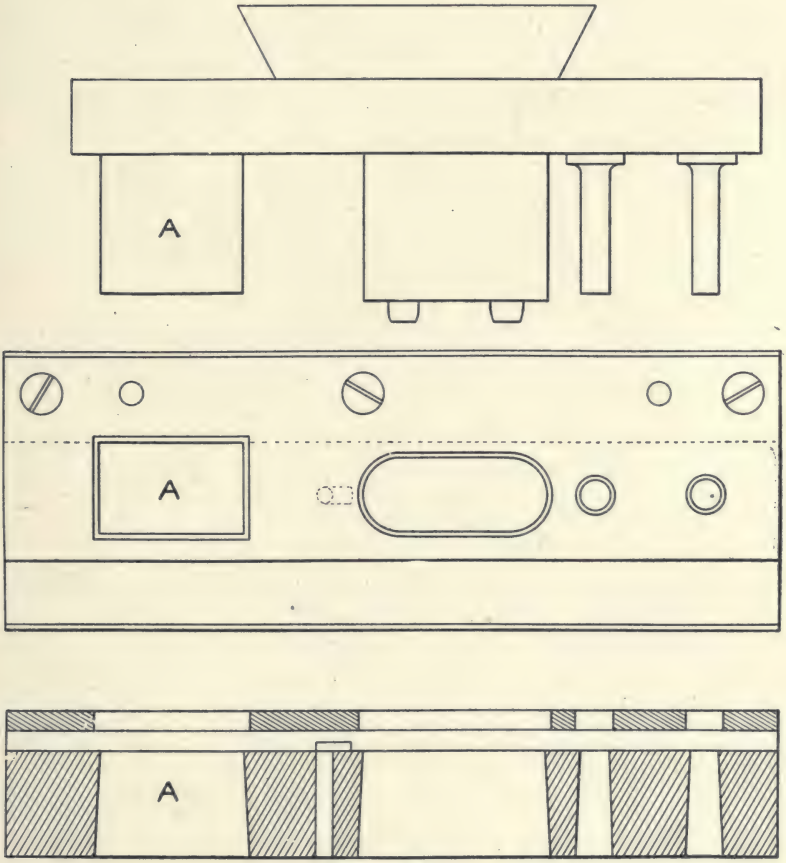


Fig. 284.

trimming die; the punch working in this cuts away the scrap leaving the edge of the sheet straight.

MULTIPLE DIE.

When making a die for punching pieces whose outline will allow it, it is sometimes advisable to make several openings of the same outline so arranged that as many pieces may be punched at a time as there are openings in the die block. If the work is punched in large quantities a great saving can be effected in the cost of production by the use of this form of die.

Where perforated sheet metal work is manufactured it is customary to make dies having as many as 500 punches working into one die block at a time, but as this is an unusual application of this principle it will not be considered.

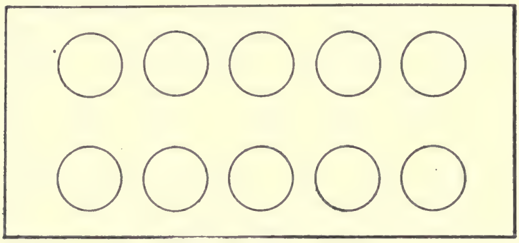


Fig. 285.

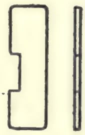


Fig. 286.

If it is necessary to punch 10 holes in the piece shown in Fig. 285 a die can be made having this number of openings. Then by making a punch holder having an equal number of punches properly located all the holes can be punched at one stroke of the press.

While in the case just cited the piece of stock which had the holes punched in it is the product, the punchings being scrap, the same principle may be applied to punching blanks from a sheet of stock by means of a multiple die.

The design shown in Fig. 286 is the product in a shop where many thousands of this piece are used monthly. The die produces a dozen or more blanks at each stroke of the press; but for convenience in illustrating the die and punches, it shows but four openings in the die with a corresponding number of punches. See Fig. 287.

If a die were made with the openings near enough together to punch the stock as shown in Fig. 288 there would be so little stock between the openings that the die would not stand up when used; for this reason the openings are located in such manner that every other opening shown in Fig. 288 is omitted. When the punch descends four blanks are punched; the stock is moved until the first opening strikes the gauge pin. This leaves the stock in position to punch between the openings already made, thus preventing waste. The next time the stock is moved until the gauge pin strikes the wall of the last opening to the right.

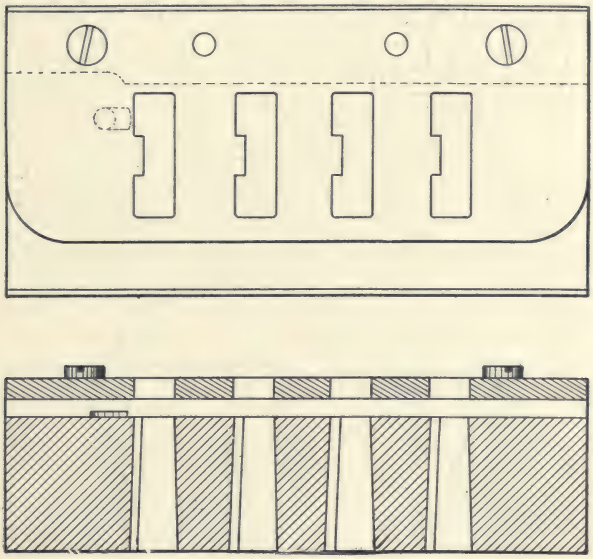


Fig. 287.

BENDING DIE.

In order to bend metals to various forms, dies are made for use in punching presses, drop hammers and various other machines. A simple form of bending die is shown in Fig. 289. The shape of the upper and lower parts of the die is such, that when the upper part is brought down on the blank B (shown by the dotted lines) it will be bent to the required shape. The shoulder A forms a locating stop against which the blank rests before bending.

When making bending dies for extremely soft metals, the dies may be made of the exact shape of the model, or the shape the piece should be when finished; but if the pieces are made from stiff material which bends with difficulty, it will be necessary to make the die of a form that will give the article **more** bend than is required as it will spring back some as soon as released by the return of the upper part.

Compound Bending Die. In Fig. 290 is shown a form of bending die used in bending bow spring and looped wire for armature connections or other looped wire work. The work is placed in the die, and the punch, as it descends, bends the wire to the shape of the die. The spring just back of the punch is compressed thus allowing the punch holder to descend and force the side benders BB toward the punch by means of the wedge pins AA, thus forming the piece in a circle.

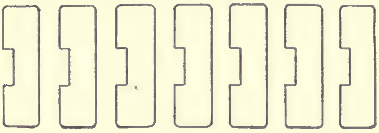


Fig. 288.

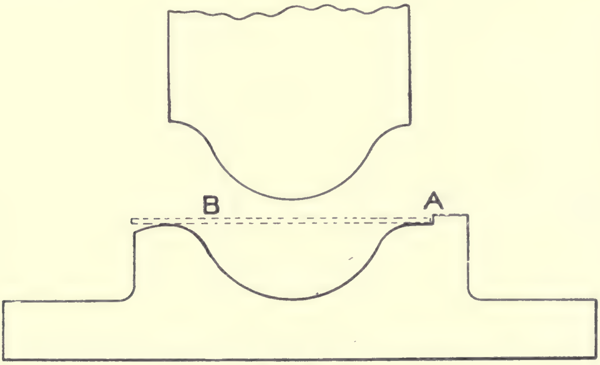
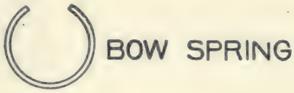


Fig. 289.

It is obvious that it is necessary to make the shape of the punch and die different. The lower die must have its bending surface, a curve of a radius equal to that of the punch plus the thickness of the material.

FORMING DIE.

This type of die is familiarly known as a *drawing die.* The most common examples of *forming* die is that used for drawing a flat circular blank, as shown at A, Fig. 291, into a cup-shaped piece, as shown at B. This operation can be done in an ordinary punching press by means of a forming die of the shape known as a push through die, from that fact that the piece is formed to shape, and pushed through the die at one operation. This form of die is shown in Fig. 292. The face of the die is cut to receive the blank; this depression is known as the *set edge*. The opening in the die is given a "draw" of $\frac{1}{4}$ to $\frac{1}{2}$ of a degree making it larger at the top, the upper edge is rounded over and left very smooth. The bottom edge of the opening is made very sharp in order that the piece may not be carried back with the punch as it returns.



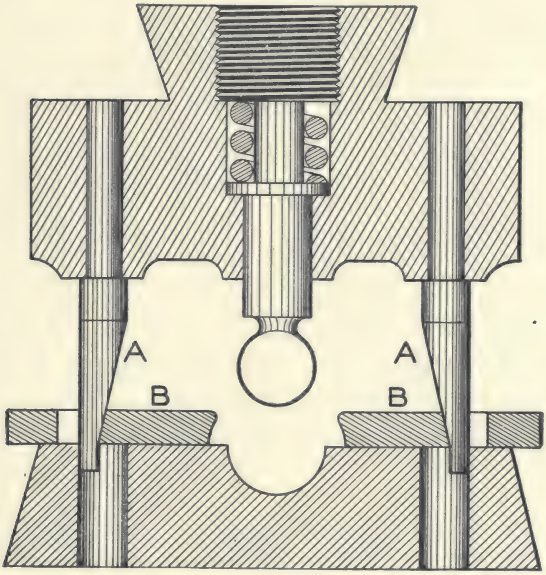


Fig. 290.

This form of die is left as hard as possible, and the walls of the opening are made as smooth as they can be polished. It is sometimes advisable to finish the walls with a lateral rather than a circular finish.

MAKING GAUGES.

Gauges are used in machine shops in order that a part of a machine, apparatus, or tool may correspond with some other part, so that when it is assembled every part may go in its place with little or no fitting.

In shops where work is made on the interchangeable plan, that is, a piece of work made to-day will exactly duplicate a similar piece made at some time in the past, a very thorough system of inspection is necessary. In order that the inspection may accomplish the desired result, gauges are made that show any variation of the pieces from a given standard.

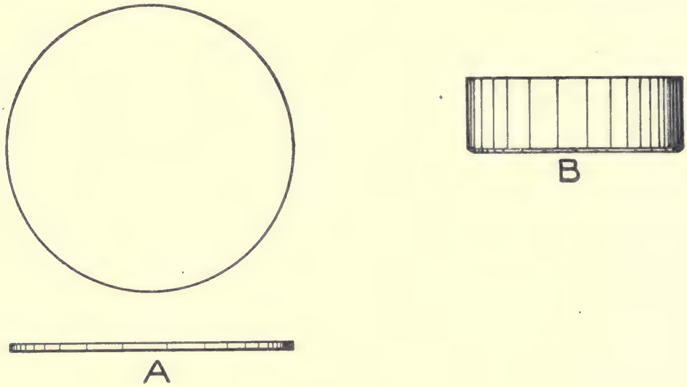


Fig. 291.

There are several forms of gauges in use for various classes of work, but only those in common use in the general machine shop will be considered here.

Gauges are generally made of *tool steel*; but *hardened tool steel* has a tendency to change its size or shape at a considerable time after the hardening takes place. This change is ascribed by acknowledged authorities, to a rearrangement of the minute particles or molecules of the steel, whose original arrangement had been changed by the process of hardening. While this change of size or shape is small, so small indeed, that it need not be considered except in the case of gauges where great accuracy is required, yet it has led some manufacturers to use machinery steel.

If tool steel is used, the tendency to change its shape may be overcome to some extent by grinding the gauge to within a few thousandths of an inch of finish size and allowing it to "season" as it is termed among mechanics; that is, it is laid aside for a few months or a year before finishing to size. This method is open to serious objection if one is in a hurry for a gauge.

To save time, it is customary in many shops to draw the temper to a straw color, allowing the gauge to cool off slowly; this operation is repeated several times. It is necessary to brighten the steel each time before drawing the temper in order that the colors may be readily seen; as this very materially softens the gauge it will not last as long as if left hard.

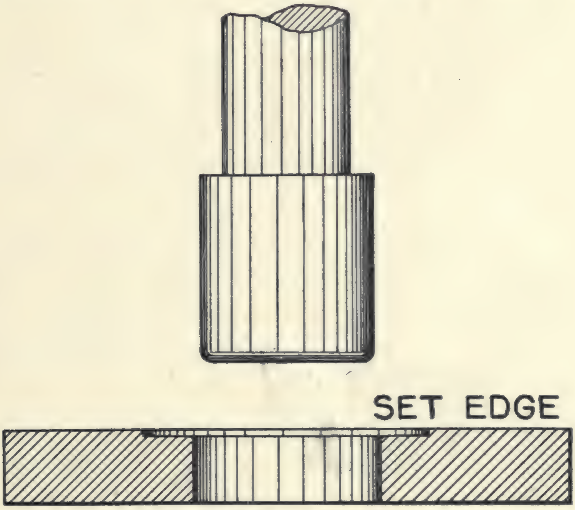


Fig. 292.

Accuracy in Gauge Making. When making gauges the workman should observe the points emphasized under "Approximate and Precise Measurements." While gauge making is generally considered very accurate work, unnecessary accuracy should not be used. If a gauge is intended for work where a variation of .005 inch is permissible, it is folly and a needless waste of time to attempt to make the gauge within a limit of variation of .0001 inch. On the other hand if the gauge is to be used as a test gauge on work requiring *great accuracy* it is necessary to use every possible effort to make it accurate.

If a gauge is to be made of tool steel, it is necessary to first remove all the outside portion (skin) of the stock, and "block" the gauge out some where near to shape; it should then be thoroughly annealed. If the gauge is flat, and should spring while annealing it *should not* be straightened cold, as it would be almost sure to spring when hardened.

It is necessary to stamp the name of the part to be gauged and the sizes of the different parts of the gauge. The workman should bear in mind that the effect of driving stamps, letters, or figures into a piece of steel will be to "stretch" it, consequently it is advisable to stamp the gauge before finishing any of the gauging portions to size, even if the gauge has an allowance for grinding.

PLUG AND RING GAUGE.

Plug gauges are used to gauge the size of a hole, while a ring gauge is for measuring a cylindrical piece of work.

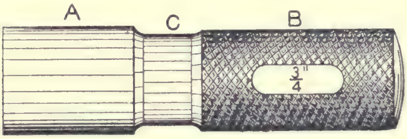
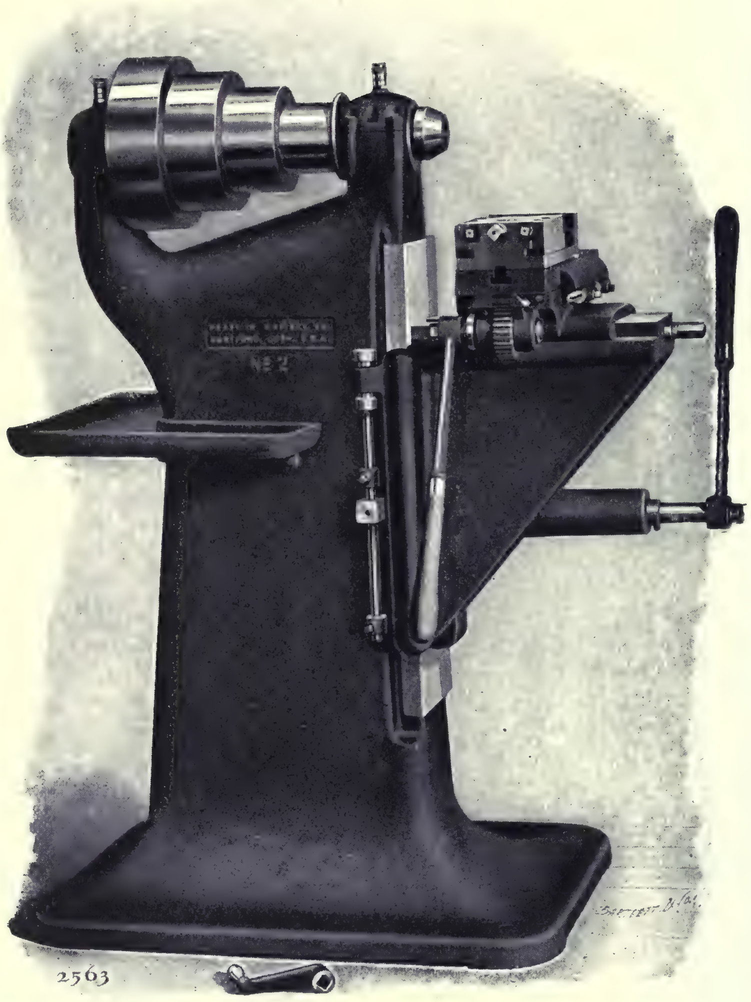


Fig 293.

To make a plug gauge as shown in Fig. 293, stock should be selected enough larger than finish size to allow for turning off the decarbonized surface. After roughing out, the handle B should be turned to size and knurled, the portion C should be turned to size and finished, the spot in the center of the handle should now be milled and the size of the gauge and any distinguishing mark or name of the article to be gauged should be stamped as shown. Or, as is the custom in many shops, the stamping may be done at C. After stamping, the gauge end A may be turned to a size .010 or .015 inch larger than finish to allow for grinding. Plug gauges should be heated very carefully for hardening, remembering that the lower the heat, the more compact will be the grain, and a piece of steel whose grain is fine and compact will wear better than one whose grain is coarse. If the gauge is one requiring great accuracy, it may be left .0025 or .003 inch above size and allowed to season, provided this precaution is deemed neces-



HAND MILLING MACHINE.
Pratt and Whitney Co.

sary; if not it may be ground to a size .001 inch larger than finish, after which it must be lapped to finish size. When grinding a gauge of this description, it is advisable to use a grinding machine having a supply of water running on the work to keep it cool, but if this form of grinder is not available, the gauge should not be heated any more than is necessary. The gauge should be measured while cold, as steel always expands from the action of heat, and a gauge ground to size when heated would be too small after it had cooled.

When grinding work of this nature, it is advisable if possible to use a form of grinder having two dead centers, that is, one in which neither center revolves. This is mentioned on account of the tendency in some shops where there is no universal grinder, (and an engine lathe is to be used as a grinder) to select the poorest lathe in the shop for the purpose. Lathes that have been in use for some time are very likely to have become worn, so that accurate work is impossible; this is especially true of the head spindle which will duplicate its untruth on the piece being ground.

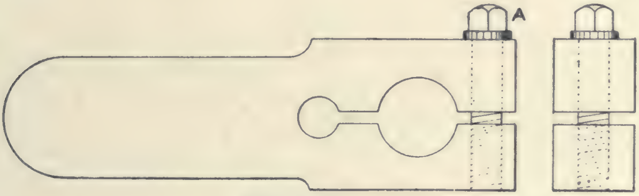


Fig. 294.

If obliged to use a machine of this description, it is advisable to leave a trifle more stock for lapping than if a suitable grinder is at hand. When grinding, a coarse wheel free from glaze should be used to grind within .004 of finish size, after which a finer wheel may be substituted to grind to lapping size.

A very simple method of making a lap for lapping a cylindrical surface is shown in Fig. 294; this consists of a piece of cast iron having a hole bored a trifle larger than the size of the gauge to be ground. It is split as shown, and is closed by means of the screw A.

If there is much gauge, or similar work, requiring lapping it is advisable to make a lap as shown in Fig. 295. The holder A has a hole bored to receive the laps which are made in the form of rings fitting the holder as shown; these rings are split in three places. One cut is carried *through* one wall, while the other two commencing at the inside, terminate a little distance from the outside surface. The laps may be held in place by means of the pointed screw shown at B.

The lapping should be done with flour emery mixed with oil. This operation has the effect of heating the gauge to a degree that would make it unsafe to caliper. On this account it is necessary to have a dish of water handy in which to cool the gauge before measuring it. This water should not be *cold*, or incorrect measurements will result; it should be as nearly as possible the average temperature of the room in which it is to be used, (about 70 degrees).

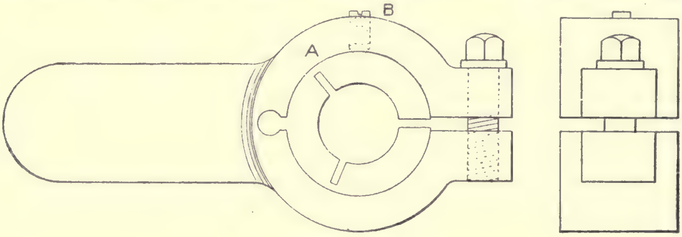


Fig. 295.

When plug gauges are made of machinery steel they should be case hardened in the following manner. They may be packed as for "Pack Hardening"; that is, using charred leather as the packing material. They should run in the furnace for 7 or 8 hours; *after* they are red hot, the box should be taken from the furnace and allowed to cool, after which the gauge may be heated in an ordinary fire enclosing it in a piece of tube. When it reaches a low red heat, it should be plunged in a bath of raw linseed oil. It will not be necessary to draw the temper, and the danger of alteration as it ages is done away with.

The reason for not hardening when the gauge has run the required length of time in the furnace is that the effect of the *second* heat is to refine the steel, making the grain more compact, like *properly* hardened *tool steel*, thus increasing its wearing qualities.

After the gauge has been lapped to the required size, it may be placed in a chuck on the grinding machine and the end ground off to remove any portion that is slightly smaller than the balance of the gauge, as the lapping is likely to grind the extreme end slightly tapering. In order to save time when grinding the end, the gauge may be made as shown in Fig. 296. The sectional view shows the end cupped in, leaving a wall $\frac{1}{16}$ inch to $\frac{1}{8}$ inch thick according to the size of the gauge, the larger sizes having the thicker walls; the cupping should be about $\frac{1}{16}$ inch deep and the corner left slightly rounded as shown.

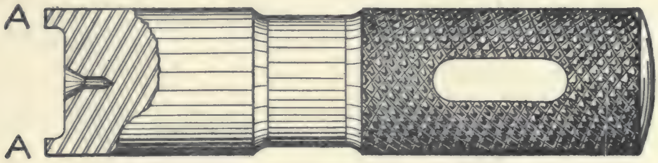


Fig. 296.

Another method is to cut a groove with a round nose cutting off tool leaving a disc on the end as shown in Fig. 297. If the gauge has its end shaped as shown in Fig. 296, the projecting end A A is ground away until the end of gauge is straight across. In case it is made as shown in Fig. 297, the disc A is broken off and the end ground as described.

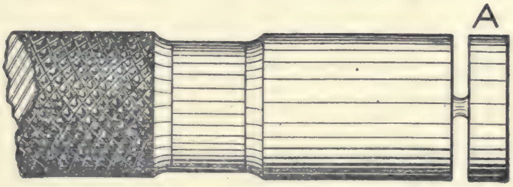


Fig. 297.

RING GAUGE.

Ring gauges intended for gauging cylindrical pieces smaller than 1 inch diameter are generally made of a solid piece of tool steel, or machinery steel which may be case hardened. For a gauge 1 inch or larger custom varies, some tool makers making it of a solid piece, while others make the body of cast iron, or machinery steel; into which is forced a hardened bushing which is the gauge proper.

It is advisable when making a solid gauge to use a piece of steel somewhat longer than finish dimensions as shown in Fig. 298. The dimension A representing the *finish* length of gauge; the projections B B being left until the gauge is lapped to size. The hole should be bored somewhat smaller than finish size in order to allow for grinding and lapping. If a grinder having an internal grinding attachment is not available, the allowance should be much less than if it were possible to grind the walls of the hole. If the gauge is to be ground to size an allowance of .005 inch will be sufficient; if not to be ground and the hole is bored straight and smooth, allow .0015 to .002; but the amount left cannot be given arbitrarily, as much depends on the condition of the hole, and the care used in hardening.

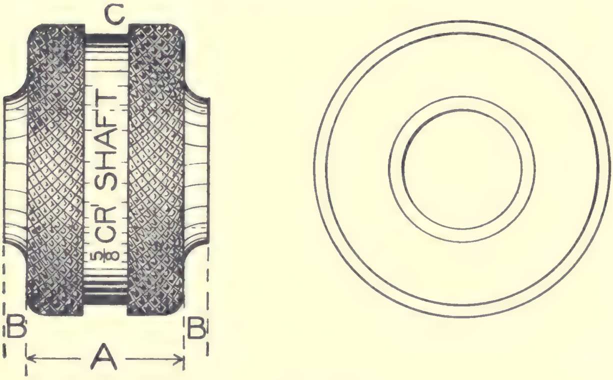


Fig. 298.

After boring the hole the blank may be placed on a mandrel the ends shaped as shown in Fig. 298, the outside diameter turned and knurled, and the portion C necked to the bottom of the knurling. The size and any distinguishing marks may be stamped on this necked portion as shown. The gauge is now ready for hardening; much better results may be obtained if the gauge is pack hardened. If this method cannot be used, the gauge should be carefully heated in a muffler furnace or in a piece of gas pipe or iron tube in an ordinary fire. When it reaches a *low uniform* heat it should be plunged in a bath of brine and worked around so that the bath may circulate freely through the hole; excellent results can be obtained if a bath is used having a jet of brine or water coming up from the bottom and passing through the hole with some force in order to remove any steam that may be generated.

If it is considered necessary to allow the gauge to "season," the hole may be ground enough to remove part of the allowance, and the gauge laid away. If it is not considered necessary to do this it may be ground .001 or .0015 inch smaller than finish size to allow for lapping.

When lapping a ring gauge to size, it is necessary to use a *suitable* lap. A poor lap is the cause of many of the failures when attempting to do satisfactory work of this description.

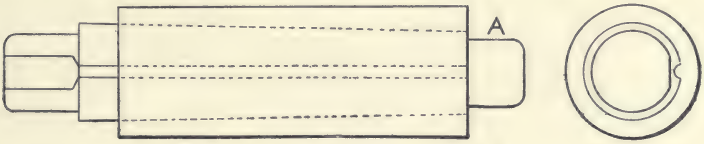


Fig. 299.

When a grinder having an internal grinding attachment is not available, and it is found necessary to leave considerable stock in the hole for lapping, many tool makers claim best results from using two laps; the first, a lead lap, for removing most of the stock; and the second, a cast-iron lap for finishing the hole to size. In either case, the lap should be in the form of a shell which should be held on a mandrel when in use. Fig. 299 shows a lead lap on a mandrel as described.

The mandrel should be made with the ends somewhat smaller than the body which should be tapering in order that the lap may be expanded as it is driven on. A groove is cut the entire length of the body with a convex milling cutter, or it may be cut in the shaper or planer, holding the mandrel between centers, or in the vise, cutting the slot with a round-nosed tool. A mold for casting the lead to shape may be made of two pieces of wood an inch or two longer than the desired length of lap which should be three times the length of the hole in the gauge. The two pieces of wood should be clamped together, and a hole bored with a bit about $\frac{1}{8}$ inch larger than the diameter of the finished lap; after boring to the required depth, a bit should then be used the size of the projection on the small end of the mandrel; the hole bored with this bit should be a trifle deeper than the length of the projection. After the hole has been bored in the mold as described, the mandrel may be put in position as shown in Fig. 300 with the mold in a vertical position. Two narrow strips of wood or metal are placed on top of the mold to hold the mandrel central in the mold. In order that the lead may *run* well, it will be necessary to heat the mandrel somewhat; this should be done before putting it in the mold.

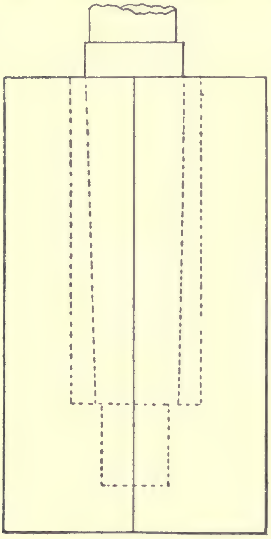


Fig. 300.

After the lead has become cool the mold may be opened, and the casting removed. It should be placed in the lathe on the mandrel, and turned to a size .001 inch smaller than the hole in the gauge; it may then be charged with emery, using fine emery and oil.

For finishing the hole to size, or lapping a hole *ground* nearly to size, it is advisable to use a lap made of harder material than lead; for this purpose fine-grained cast iron answers admirably, although copper is preferred by some. In order to make a cast-iron lap, a mandrel is necessary, which should taper $\frac{1}{8}$ to $\frac{3}{16}$ inch per foot of length. The slight taper is used in order that the lap may not increase its size too rapidly when driven on the mandrel. The cast-iron lap (sleeve) should be bored with a taper corresponding to the taper of the mandrel, after which it may be forced on the mandrel and turned to size and split as shown in Fig. 301. One slot should extend through the wall as shown at A (end view), while the other two slots B B extend deep enough to allow the lap to expand readily. Before finishing the hole to size the lap should be forced a trifle farther on the mandrel, and trued in the grinder using an emery wheel to cut the lap. The lap should be *perfectly round* and *straight*, in order to produce true holes. For the finish lapping the finest of flour emery should be used. The same precautions should be observed while cooling the gauge before trying the size of hole, as were noted under "Lapping Plug Gauges." In order to clean the gauge of the oil and emery, it should be dipped in a can of benzine, which readily removes any dirt. Extreme care should be exercised when washing work in benzine that it is not brought in the vicinity of a flame of any kind, as it is *extremely* inflammable, and very difficult to extinguish if it becomes ignited; should it become ignited it can be extinguished with a piece of heavy sacking.

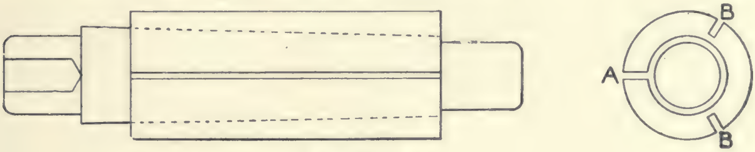


Fig. 301.

The ring should be fitted to the plug gauge which has previously been finished to the correct size. It must be borne in mind that the temperature of the plug and ring should be as nearly the same as possible when testing.

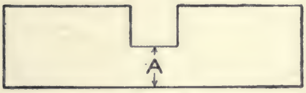


Fig. 302.

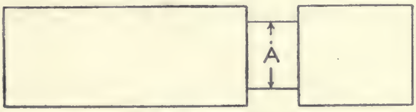


Fig. 303.

SNAP GAUGE.

This form of gauge is used more extensively than any other for outside measurements; it is extremely useful in gauging a dimension between two shoulders as shown at A, Figs. 302 and 303; in the former case the piece being machined is flat while in the latter it is cylindrical.

Snap gauges may be designed to meet the requirements of the particular piece of work upon which they are to be used. When a gauge of this description is intended for use on a cylindrical piece, the opening should be made a trifle deeper than one-half the diameter of the piece to be measured.

When a snap gauge is intended for flat work, the depth of the slot depends on the nature of the work.

Snap Gauges for Cylindrical Work. As previously stated when snap gauges are to be used for gauging cylindrical pieces it is necessary to make the opening a trifle deeper than one-half the diameter of the piece to be measured, as shown in Fig. 304, in which A represents the cylindrical piece to be gauged.

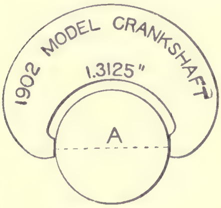


Fig. 304.

When making a snap gauge of this form the stock should be blocked out somewhere near to shape and annealed; after annealing the sides may be made flat and parallel, and the size and any distinguishing marks stamped as shown, after which the gauge part may be worked to a size .008 to .010 inch smaller than finish to allow for grinding. The outer edges should be rounded somewhat to prevent cutting the hands of the operator.

When hardening gauges of this type, some tool makers harden only the prongs that come in contact with the work, while others harden the entire gauge. If the contact points alone are to be hardened, the heating can best be done in a crucible of red-hot lead, but if this is not at hand a piece of flat-iron may be placed each side of the gauge, allowing the ends to be hardened to project beyond the pieces; the whole may now be grasped in a pair of tongs, and placed in the fire. The points will reach a hardening heat before the portion between the flat pieces is very much heated. It may be plunged in water or brine to harden.

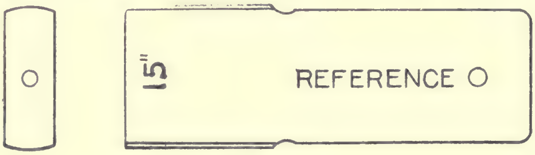


Fig. 305.

If it is considered advisable to harden the gauge all over, it should be heated very carefully in the fire, making sure that the blast does not strike it; turn it frequently to insure a uniform heat. When it reaches a low red heat remove from the fire and plunge in the bath; if the gauge is quite thin a bath of oil will harden sufficiently; if it is dipped in water or brine the bath should be warmed somewhat in order to avoid as much as possible any tendency to spring.

After hardening, the gauge is ground to a size .0005 inch smaller than finish and lapped to size; the method used in grinding gauges of this character will be described later.

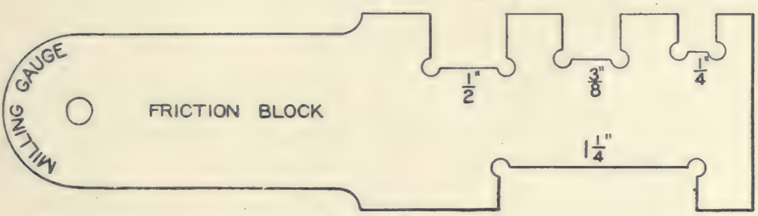


Fig. 306.

In order to be able to give gauges the correct size, it is often necessary to make male gauges. The simplest form of male gauge is shown in Fig. 305; it is a flat piece of tool steel, made slightly small on one end to avoid grinding to size the entire length. After hardening the large end, it is ground to size; it is then ready for use in testing the size of the female snap gauges while the latter are being lapped to size; or when grinding if lapping is not considered necessary. When it is necessary to make a snap gauge for gauging two or more dimensions on a piece of work, the gauge may be made as shown in Fig. 306, while Fig. 307 represents the piece to be gauged.

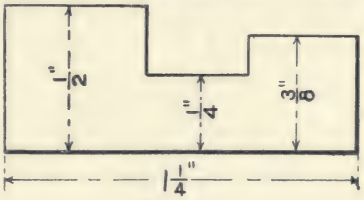


Fig. 307.

After cutting off the steel for the gauge, the sides may be planed to remove the "skin." One of the flat surfaces may be colored with blue vitriol, or it may be colored by holding over a fire until the surface becomes blue. The handle and the openings that constitute the gauges may be laid off on the surface. After milling the handle to shape the holes shown at the corners of the openings may be drilled; these holes facilitate the operations of filing and grinding, particularly the latter. The openings may be milled or planed to a size somewhat ($\frac{1}{32}$ inch) smaller than finish and the gauge is ready for annealing. After it is annealed the two flat surfaces may be planed or filed until flat and parallel. The name of the piece to be gauged and the size of the openings may be stamped as shown. If the gauge is intended for gauging work where a few thousandths of an inch either way would make no particular difference, it is customary to make the openings to the given sizes before the gauge is hardened. However, if the gauge must be exact to size, it is necessary to leave from .003 to .005 inch on each measuring surface to allow for grinding, and if it is desirable to have the gauge retain its exact size for any considerable length of time, it will be found necessary to finish the gauge to size by lapping *after* it is ground.

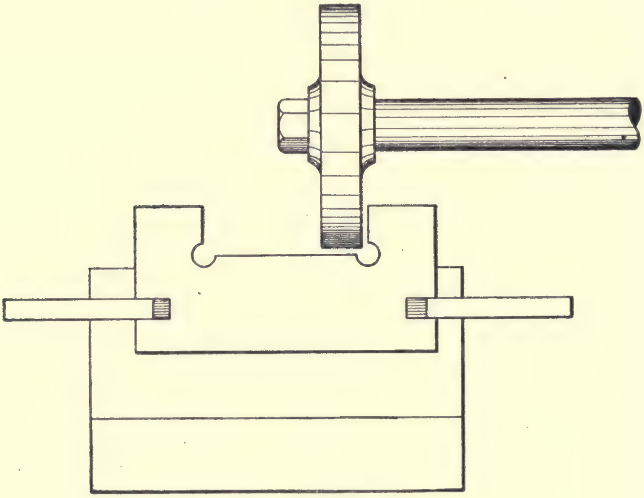


Fig. 308.

Grinding Snap Gauges. Snap gauges may be held in a vise on the universal grinder when grinding the openings to size provided the gauge is held in such a manner that it cannot spring. If it were sprung in any manner while being held, it would assume its normal shape when taken from the vise, and consequently the measuring surfaces would not be parallel. This would destroy the accuracy of the gauge, as it is highly important that the measuring surface of the opening be parallel.

A snap gauge may be clamped to an angle iron which may be held, while grinding, in the vise as shown in Fig. 308, or it may be clamped to a piece of machinery steel or cast iron which is centered as shown in Fig. 309. This holder should be placed between the centers of the grinding machine.

If the opening whose gauging surfaces are to be ground is of sufficient width, an emery wheel of the form shown in Fig. 310 may be used, or a wheel may be recessed on its sides as shown in Fig. 311. If a wheel of the form shown in Fig. 310 is used it will be necessary to remove the wheel after grinding one wall of the opening and reverse it to grind the other. If, however, the opening is too narrow to allow a wheel of the form shown above to be used, a very thin wheel may be made to answer the purpose, but it will be necessary to swivel the head of the grinder a little in order that the wheel may touch the surface to be ground only at the corner of the wheel.

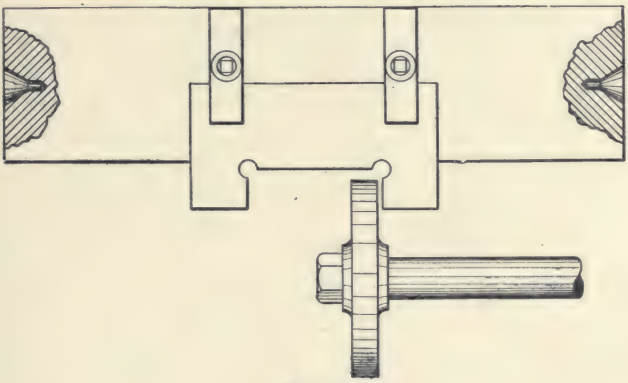


Fig. 309.

If a grinding machine is not available, an engine lathe or a bench lathe can be used. If the lathe is provided with a grinding attachment, the holder to which the gauge is attached may be placed between the centers of the lathe, and the grinding attachment used in the ordinary manner. If the lathe is not provided with a grinding attachment the emery wheel may be mounted on an arbor between the centers of the lathe. The arbor may be driven from any accessible pulley either on some overhead countershaft or some machine having a pulley in line with a small pulley on the arbor, on which the driving belt is supposed to run. If this method is used it will be necessary to have hardened centers in both head and tail spindles. If a *thin* wheel is used in grinding the surfaces of a narrow opening, the tail center of the lathe may be set over each way to give the desired amount of clearance to the side of the emery wheel. The holder mentioned may be fastened to the tool rest, or the gauge may be fastened to the rest as shown in Fig. 312. At the right is shown a side view of one of the clamps used in holding the work to the rest while grinding; the center is represented as being cut away in order that it may bear at its ends thus removing any chance of its tipping the work being ground.

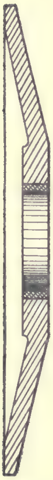


Fig. 310.

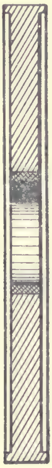


Fig. 311.

Lapping a Gauge to Size. Where it is essential that gauges retain their exact size for a considerable length of time, the gauging surfaces must be lapped to size after grinding. The surface left by the emery wheel, even when the utmost care is used, consists of a series of small ridges or irregularities which wear away as the gauge is used and leave the opening too large; lapping the gauging surfaces with oil and emery grinds these minute particles away, leaving a perfectly flat surface, thereby increasing the durability of the gauge.

A convenient form of lap for use in lapping the gauging surfaces of snap gauges is shown in Fig. 313. It consists of a piece of copper or brass wire, bent as shown; the surface A is filed or hammered flat and charged with some abrasive material, as emery; extreme care must be used in lapping the surfaces that they remain perfectly flat and parallel. Unless the operator has had considerable experience in this particular branch of the business, he will be likely to cut the edges away more than the center. To avoid doing this, pieces of hardened steel may be clamped to each side of the gauge before grinding, as shown in Fig. 314. As the tendency when lapping is to make the outer edges round, the portions rounded will be the edges of the pieces clamped to the gauge. After the gauge has been lapped to size these pieces may be removed.

Adjustable Snap Gauge. Snap gauges that are in *constant* use soon wear to an extent that renders them useless, making it necessary to close them in and grind and lap them to size again, or else replace them with new gauges. This tendency to wear and the consequent labor and cost of resizing or replacing has caused the adoption of a style of snap gauge whose size could be altered when necessary; this form of gauge is styled an adjustable snap gauge.

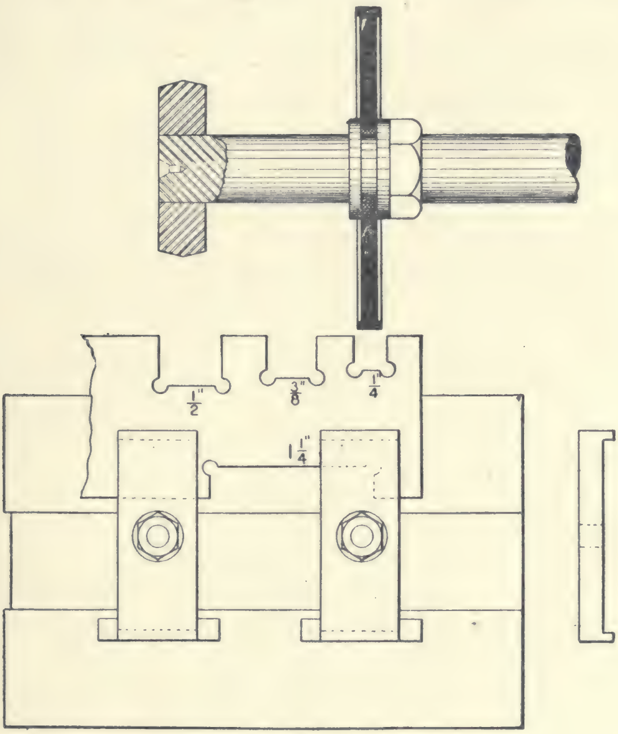


Fig. 312.

The method of adjustment differs in different shops. Fig.

315 represents a form of adjustable snap gauge which is not expensive and gives excellent results in that its size may be readily adjusted. After blocking out the gauge somewhere near to shape, the screw hole for the adjusting screw C should be drilled and tapped, and the slot milled for the adjustable jaw. The jaw should be made as shown having a slot through which the binding screw D may pass. The jaw should fit snugly in the slot in the frame and placed in position after stamping the name and any distinguishing marks. The aperture E should be worked to a size .010 or .015 inch smaller than finish. The adjustable jaw B may now be removed and the gauging (or contact) surface hardened, being careful not to harden the entire length of the large portion or a crack may appear in the sharp corners on account of the unequal size of the two portions. In order to heat the contact surface and not heat back into the sharp corners, the face may be immersed in red-hot lead, leaving just long enough to sufficiently heat the face; or the smaller portion may be held in a pair of tongs letting the end of the jaws come against the shoulders of the piece. It may then be heated in a gas jet or ordinary fire. For most purposes it will not be necessary to harden the gauge all over; if the gauging portion A is hard

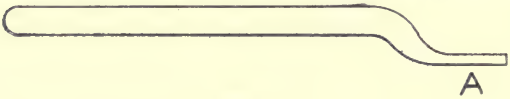


Fig. 313.

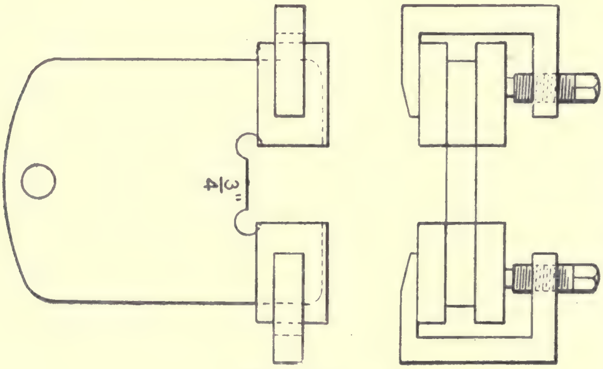


Fig. 314.

ened it will be found sufficient. After hardening, the gauge may be assembled and ground and lapped as already explained.

LIMIT GAUGE.

Where it is not necessary that work be of exact size, and a small limit of variation is permissible, limit gauges are used. They prevent a waste of time in attempting excessive accuracy, yet leave the work so that the corresponding parts when brought together will fit well enough to meet requirements.

These gauges are also valuable in roughing work for finishing.

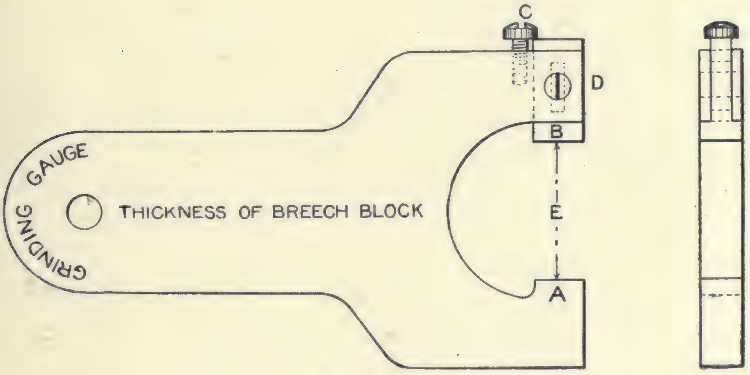


Fig. 315.

When so used practically the same amount of stock is left on each piece, thus facilitating the finishing process.

If a cylindrical piece is to go in a reamed hole, and the piece fits well enough for all requirements when .003 inch smaller than size of hole, it is folly to spend the time necessary to get a more accurate fit.

The amount of variation allowable must be decided in each case; on one job a limit of variation of .001 inch might be all that could be allowed, while on another piece of work .010 inch might be allowable.

In deciding the allowable limit of variation it is advisable, where it is possible, to take into consideration the natural changes that take place in a gauge from wear. For instance, suppose a piece of work .250 inch in diameter just fills the hole it is to go in, and a limit of .0015 inch is allowable; that is, if the piece is

.2485 inch to .250 inch diameter, it would be folly to make the large end of limit gauge for this work .250 inch as there would be no allowance for wear of either the external or internal gauge.

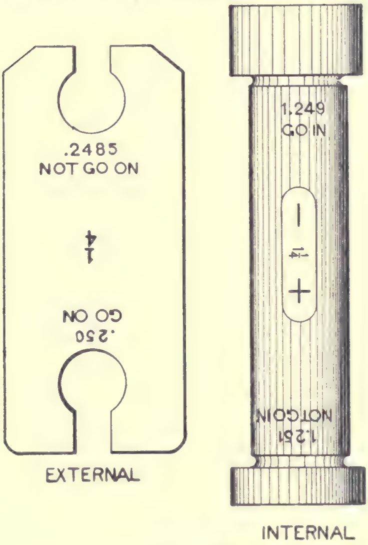


Fig. 316.

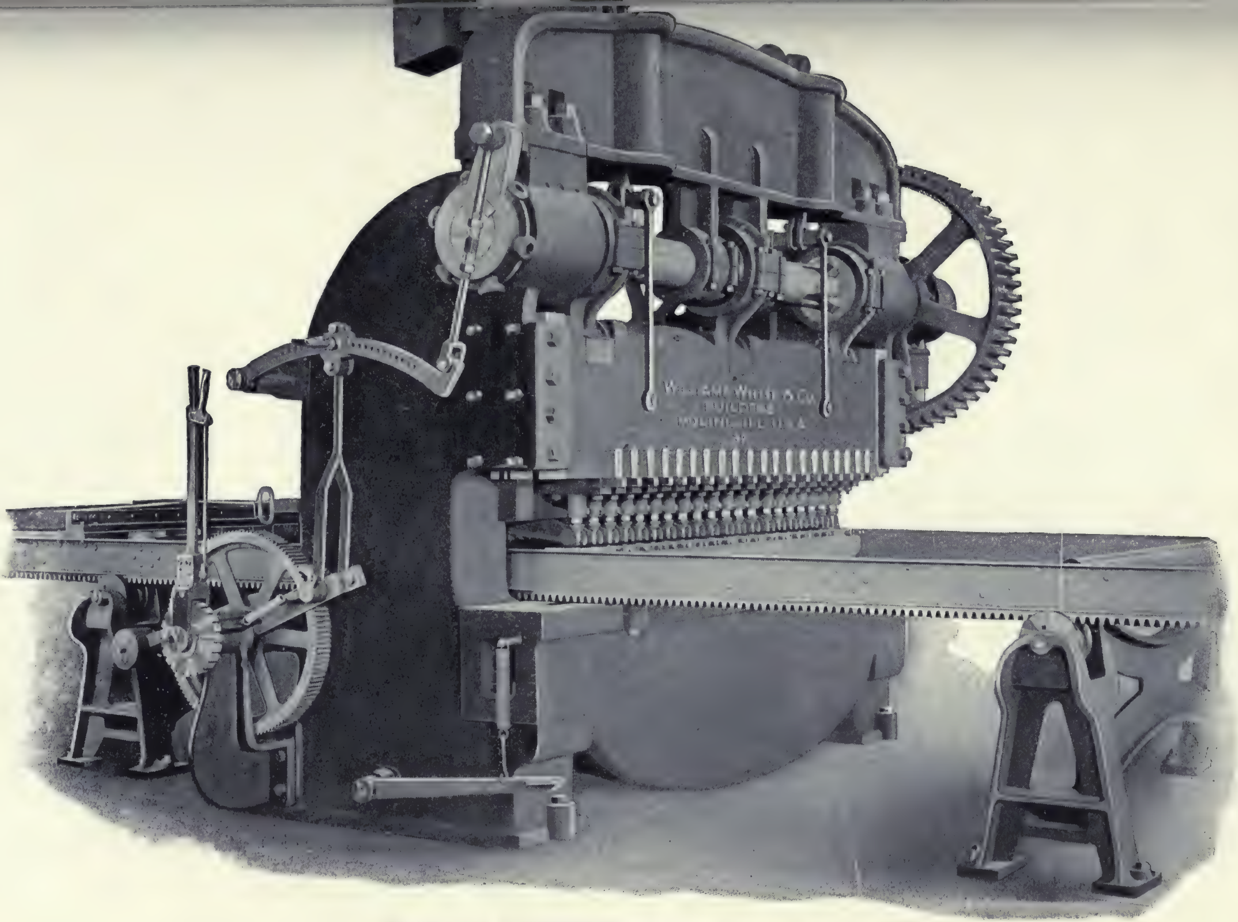
Fig. 316 gives an idea of one form of a snap gauge used for external measurements; however, it is not necessary to make them of the styles shown. The plug gauge may be made as shown in Fig. 317; while the snap gauge may be made as shown in Fig. 318. The same general instructions given for making plug gauges and snap gauges apply to limit gauges of the same character.

RECEIVING GAUGE.

When it is essential that the various working points of a tool, part of a machine or apparatus should be in exact relation to one or more given points, a receiving gauge is used. This gauge as the name implies is made to *receive*, or take in, the work; that is, the piece of work is *placed in* the gauge, and the exact location of the different points is determined by the eye.

Fig. 319 shows a gun-hammer, while Fig. 320 represents a receiving gauge for *accurately* gauging the points C, D, E, F, G and H in relation to the fulcrum screw hole A and the face B. These points must also be in exact relation to each other; hence the necessity of a gauge, of this character. When making a gauge of this type, it is customary in most shops to gauge only those parts that must be located in exact relation to some other point or points.

In the case of the gun hammer under consideration the fulcrum-screw hole A must be the main working point because when it is operated it is pivoted at this point, consequently every point



MULTIPLE PUNCHING AND SHEARING MACHINE

With Automatic Spacing Table.

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must be in exact relation to this hole. The point of next importance is the face B which strikes the firing pin; in order that the face of the hammer may be the proper distance from the firing pin when half cocked, or full cocked, it is necessary that the half cock notch D, and the full cock notch E be properly located as regards the face of the hammer. They must also be in exact location as regards the fulcrum-screw hole A. In order that the main spring may exert the proper amount of force on the hammer, it is necessary that the spring seat G be exactly located. As the portions marked C and H are intended to just fill the opening in the gun frame when the hammer is in any position, it is necessary that they be located the proper distance from the center of the fulcrum-screw hole A; hence the need of a gauge that will determine the exact location of all points as related to A and B and to each other. As the por-

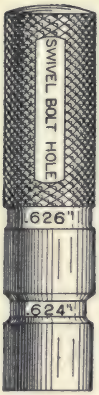


Fig. 317.

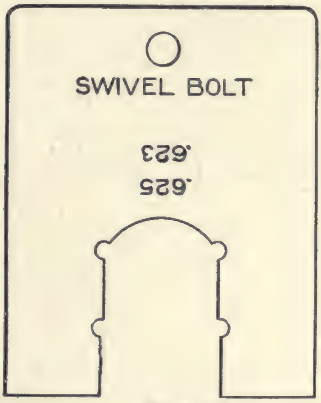


Fig. 318.

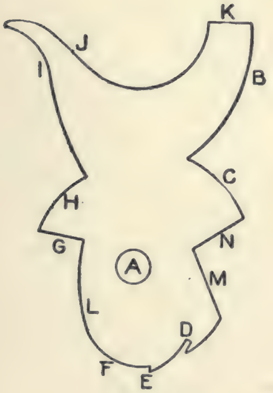


Fig. 319.

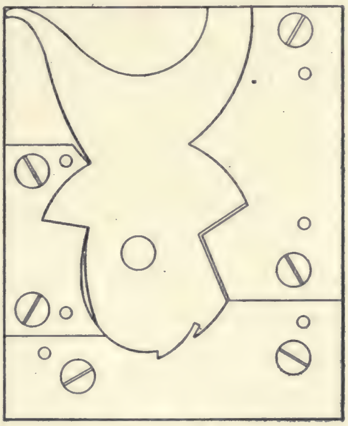


Fig. 320.

tions marked I, J, K, L, M, and N must be in *exact* location to the other points or to each other they are gauged with a *separate* gauge because each additional gauging point on a gauge of this description complicates matters.

When making gauges of this character a piece of machinery steel is usually taken for the base; this is planed to size and ground or filed for finish; a hole is drilled and reamed to receive a pin the size of the fulcrum screw hole. This pin is made of a piece of drill rod a few thousandths inch larger than the desired pin. The piece of drill rod should be long enough to be held in the chuck of the grinding machine, and should be cut of the proper length as shown in Fig. 321. The short end should be hardened and the temper drawn to a straw color; after which the wire may be placed in the chuck on the grinding machine and the pin ground to the desired size. After grinding to size it may be broken off and the end ground; this can be done by holding the pin in the chuck, leaving the broken end out in order that it may be ground square, the pin should now be forced to place in the hole in the base.

Fig. 321.

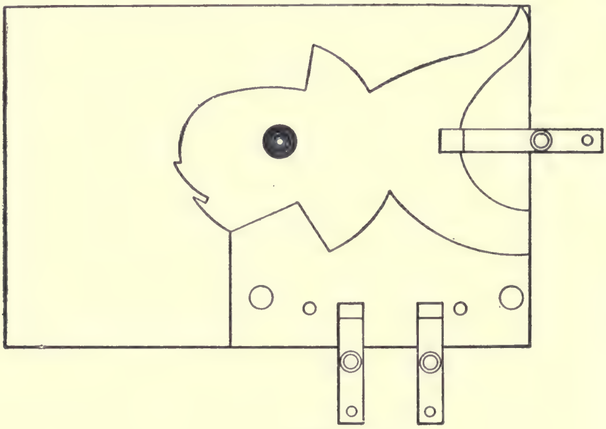


Fig. 322.

The gauge proper may be made of one plate worked to the proper shape, but better results will follow if it is made in three pieces as shown in Fig. 320 on account of the tendency of the plate to spring when hardened.

These plates may be made either of tool steel or machinery steel, if made of tool steel the pieces should be machined all over and thoroughly annealed, after which they may be planed or milled to thickness.

One surface should be colored by the blue vitriol solution, or the pieces may be heated until a distinct blue color appears; the desired shape should be marked on the colored surface and the pieces machined and filed until they fit the model, the necessary degree of accuracy must be determined by the nature of the work.

After the pieces are properly fitted to the model, they may be attached to the base by means of the fillister head cap screws shown. The model should be laid on the base having the fulcrum screw hole on the pin. After arranging the model in its proper location it may be clamped as shown in Fig. 322. The sections of the gauge which should have been previously drilled for the screw and dowel pins, may now be clamped to the base in their proper positions. After drilling, the holes in the base may be tapped, and the screws put in place. If it is found necessary to make slight alterations in any of the shapes, they may be readily made as the plates can be moved a trifle because the bodies of the screws need not fit tightly in the holes in the plates. The dowel pin holes should not be transferred into the base until after the plates are hardened.

The plates may now be removed and hardened. If of machinery steel they may be case-hardened, dipping them in oil rather than water. If made of tool steel best results will follow if the plates are pack-hardened, running them 1 to 1½ hours after red hot and then dipping in raw linseed oil.

If the process of pack-hardening cannot be used, satisfactory results may be obtained if they are carefully heated in a tube in an open fire, or placed in the muffler of a muffler furnace. When red hot, sprinkle a small quantity of finely powdered cyanide of potassium, or a little yellow prussiate of potash on the contact surfaces, place in the fire again, bring to a low red heat and plunge in a bath of oil.

After hardening, the plates may be attached to the base by means of the screws; if any of the gauging points have become distorted by hardening, they may be brought to the proper shape by oil-stoning.

When the plates are properly fitted and located in their exact positions, the dowel pin holes may be transferred into the base and the dowel pins put in place.

LOCATING GAUGE.

This form of gauge is used for determining the location of one or more holes in relation to another hole, a shoulder, or working surface, or any similar measurement.

Fig. 323 shows a gauge for showing the proper location of the hole from the edges A and B, Fig. 324. This gauge consists of a base having four pins for the edges A and B, to rest against. These pins are flatted on the contact edges to prevent wearing. The piece of work to be gauged is placed in position and clamped to the gauge with machinists clamps as shown in Fig. 325. The gauge is fastened to the face plate of the lathe in such a manner that the piece of work can be removed without disturbing the location of the gauge.

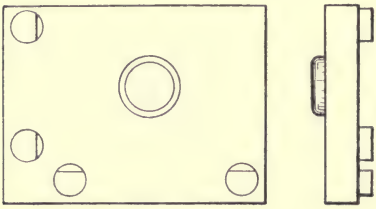


Fig. 323.

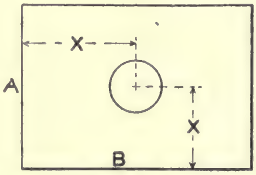


Fig. 324.

A short plug is now inserted in the hole in the model. It is necessary that the plug should fit very accurately. By means of a lathe indicator the gauge can be located so that the plug runs perfectly true. When this has been accomplished the model may be removed and the bushing hole drilled and bored to size; after which the bushing may be made, hardened, ground to size, and forced to place.

The location of the drilled hold may be tested by placing the piece of work on the gauge against the pins, and entering the gauge pin in the hole in the work and bushing, as shown in Fig. 326. If the pin is a close fit in the holes a very slight error in location may be detected. When a slight error in location is allowable, and it is not considered advisable to hold the location too close, the pin may be made a trifle small, thus transforming the gauge into a limit gauge.

When it is necessary to make a locating gauge for testing the center distance of two holes, one pin may be made removable, while the other is rigidly fixed as shown at C Fig. 327.

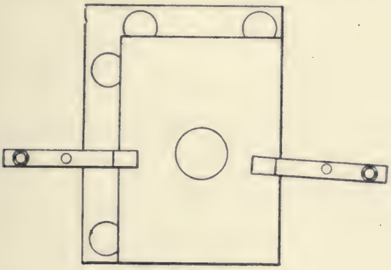


Fig. 325.

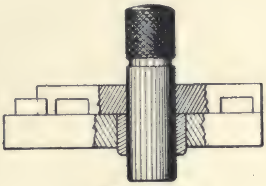


Fig. 326.

If the gauge is made with both pins fixed it is a difficult operation to remove the piece of work, provided the pins are a good fit in the holes. Withdrawing one pin allows the piece of work to be readily taken from the fixed pin.

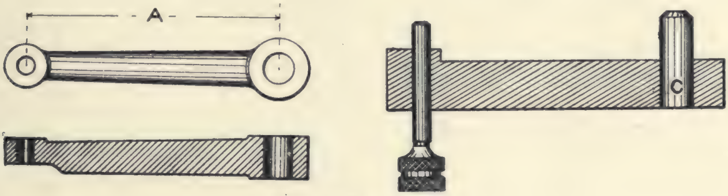
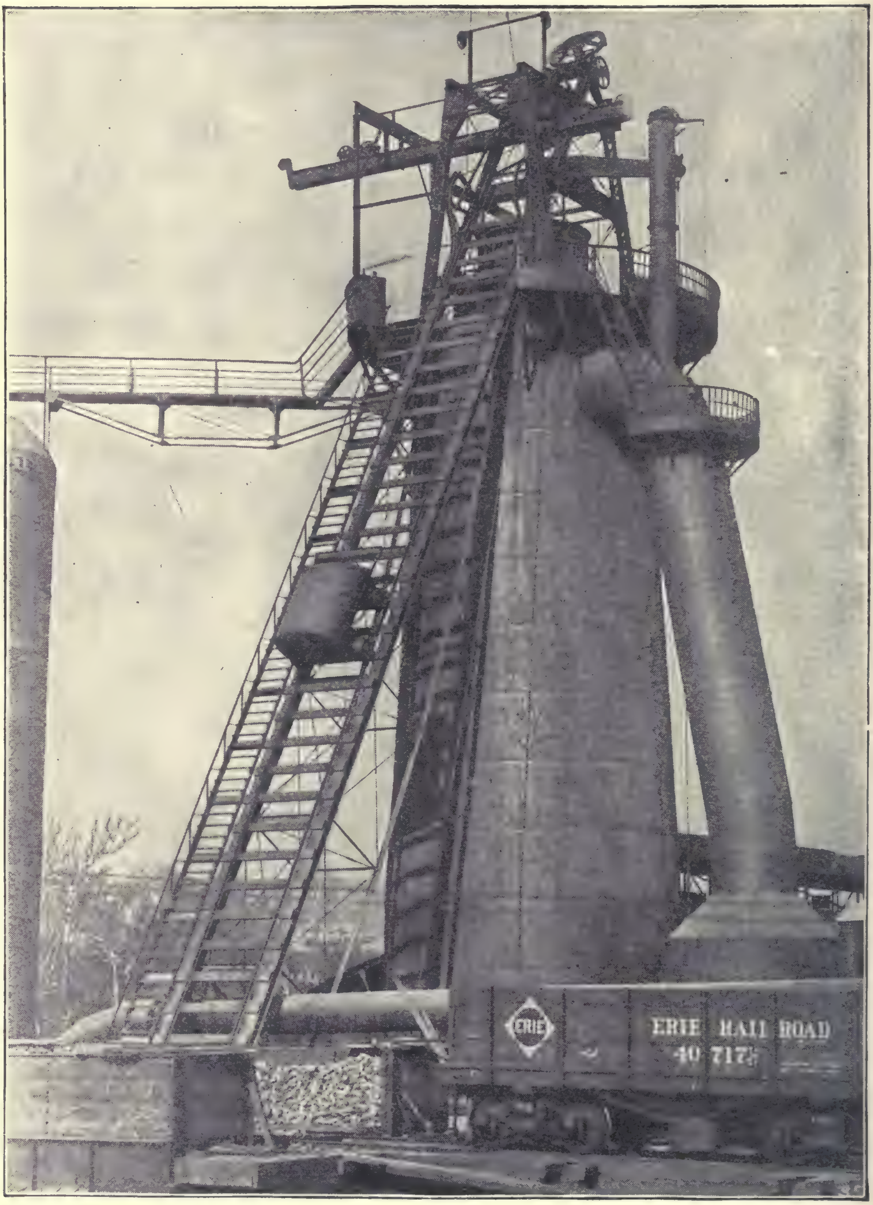


Fig. 327.

When making a gauge of the form shown in Fig. 327, the fixed pin C may be located by approximate measurements; but the hole should be drilled by some method that insures the pin standing perfectly square with the base of the gauge. If a small limit of variation is permissible in the center to center measurement A, the model may be placed on the gauge with the large hole on the fixed pin C, and the location of the hole for the movable pin may be transferred from the model by drilling and reaming. If extreme accuracy is essential, it will be advisable to place the model on the gauge as described, clamp the model to the gauge, then fasten the gauge to the face plate of lathe, place an accurately fitting pin in the small hole in the model, and by means of a lathe indicator locate the gauge so that the pin runs perfectly true. The model may now be removed and the hole drilled and bored to size.



AUTOMATIC FURNACE HOIST

For Feeding Ore and Limestone to Blast Furnaces.

METALLURGY.

IRON.

For centuries iron has been the most useful metal known to man. In the earliest periods of history, stone implements were used; later bronze, an alloy of copper and tin, replaced stone. After a time men found a way to extract iron from its ores, and the Iron Age began. As nothing has yet been discovered, or invented, to take the place of iron in the arts, the Iron Age has continued until the present day. The process of separating, or extracting iron from its ores; of smelting and refining it; and of making it into its most useful form, steel, is called the metallurgy of iron. From small beginnings, this art has gradually increased to its present importance.

ORES.

Iron is never found pure; it is always compounded with other elements or minerals. These compounds, called ores of iron, occur in enormous quantities, and are widely distributed in the earth. The value of an ore depends upon its richness, its locality, the ease with which it can be smelted, and its freedom from phosphorus and sulphur. The principal ores are:

Magnetite, magnetic iron ore (Fe_3O_4). It is black, heavy and crystalline. The finest quality is found in Sweden, and sometimes contains as high as 72 per cent metallic iron. This ore usually contains from 40 per cent to 60 per cent metallic iron. A high temperature is required to reduce it.

Hematite, oxide of iron (Fe_2O_3). A red ore containing about 70 per cent of iron when pure; it is sometimes called "Hard Ore." About 82 per cent of all the ore now mined in the United States is red hematite.

Limonite, or brown hematite ($2Fe_2O_3\ 3H_2O$). Contains water which can be expelled by heat, leaving the ore of a reddish

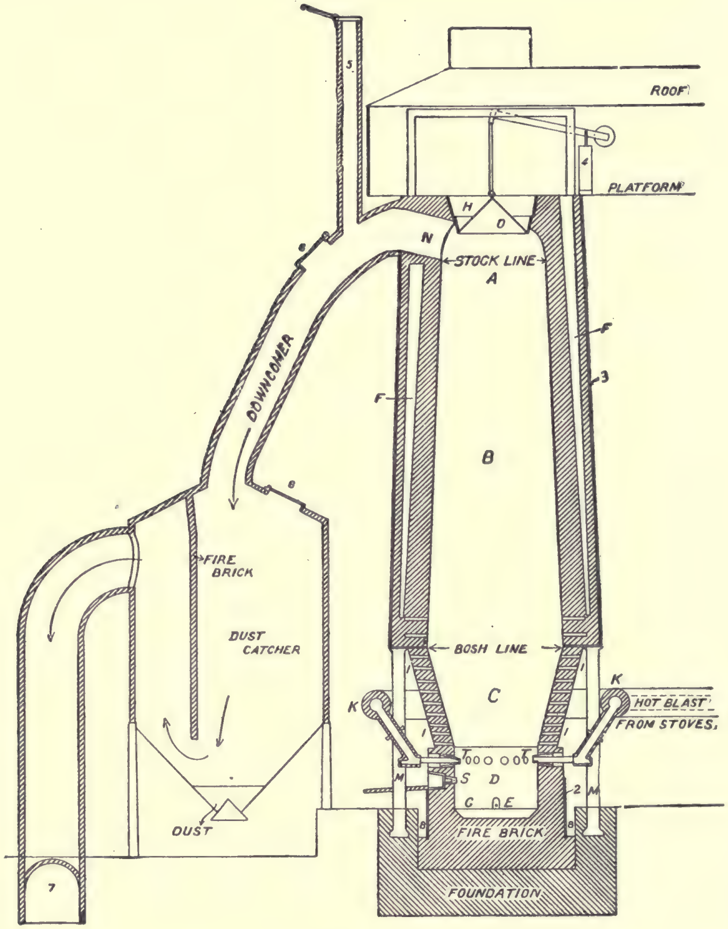


Fig. 1.

1. BRONZE COOLING PLATES.
2. CRUCIBLE JACKET.
3. SHELL.
4. BELL CYLINDER.
5. BLEEDER.
6. EXPLOSION DOORS.
7. FLUE LEADING TO STOVES AND BOILERS.
8. DITCH FOR WATER.

HEIGHT,	90 FEET.	DIAMETER AT STOCK LINE,	15 FEET.
DIAMETER AT BOSH LINE,	20 FEET.	HEIGHT OF TUYERE CENTER,	8 FEET.
DIAMETER AT CRUCIBLE,	14 FEET.	CAPACITY,	400 TONS PER DAY.

color. When pure this ore contains about 60 per cent of iron, and from 8 per cent to 20 per cent of water.

Siderite, or carbonate ($FeCO_3$) or ($FeOCO_2$). This is an important ore in Europe, although containing only about 48 per cent iron. It requires careful preliminary roasting before smelting.

Iron ores are never found pure ; they contain varying quantities of silica, alumina, calcium, manganese, sulphur and phosphorus.

MINERALS.

The principal minerals used in iron smelting are:

Iron Pyrites or fool's gold (FeS_2). It occurs in cubic crystals and bright shining scales. This mineral is used as a source of sulphur in the manufacture of sulphuric acid. In some cases it is smelted for iron after its sulphur has been used.

Franklinite, or oxides of iron, manganese and zinc (FeO MnO ZnO) ($Fe_2O_3Mn_2O_3$). It contains about 46 per cent of iron. It is used in the manufacture of zinc white and spiegeleisen. "Spiegel," is a coarsely crystalline variety of cast iron, with large crystal planes having bright reflections. It usually contains about five per cent of combined carbon and 10 per cent to 20 per cent of manganese.

Limestone, *Chalk* or *Oyster Shells*,—carbonate of calcium ($CaCO_3$). Used as a flux.

Dolomite, carbonate of calcium and magnesium [$(Ca\,Mg)\,CO_3$], sometimes substituted for limestone.

PREPARATION OF ORES.

Usually the ore is broken into small pieces and then reduced to metallic iron in the blast furnace. Sometimes it is broken into small pieces, piled up, and exposed to the air and rain. By this means dirt, sand and soft rock are washed out. In this country iron ore is seldom roasted, but when necessary it is roasted in kilns, thus driving out the sulphur.

THE BLAST FURNACE.

The blast furnace is located in a place where materials may be economically assembled, product cheaply transported to market, and a good water supply is available.

The blast furnace is a circular brick or stone structure, lined with fire brick and encased in sheet iron. The general arrangement is shown in Fig. 1. The throat at A is about 15 feet in diameter; the main portion B, called the shaft, is nearly cylindrical and about 60 feet high and 20 feet in diameter. The lower portion C, which is shaped like an inverted frustum of a cone, is called the boshes and is about 20 feet high and 14 feet in diameter in the smallest part. Below the boshes a cylindrical portion D, called the hearth, extends about 10 feet and is lined with fire brick. This total height is about 90 feet, but some are over 100 feet high. The tuyeres T, 6 to 16 in number, are pipes through which hot blasts of air are blown and are built into the brickwork about 6 feet above the bottom of the hearth. The tuyeres are made as simple as possible and constructed so that they may be easily taken out and replaced. The bustle pipe K, supplies air to the tuyeres. The part of the hearth G, below the tuyeres is called the crucible, which being subjected to intense heat, is often cooled by water flowing through a series of open gutters around it. The boshes are kept cool by water circulating through a series of cooling rings, cast in bronze blocks and set in the brick or masonry walls.

There are two openings in the crucible wall; the upper, called the cinder notch for the removal of slag or "cinder," and the lower for the molten cast iron. The upper or "slag eye" S, is stopped up by an iron plug on a long handle; but the lower or "tap hole" E must be plugged with clay. Balls of clay are rammed in and soon baked as hard as stone by the heat. For large furnaces a "gun" is used to force the clay balls into the hole. This clay is two or three feet in thickness and when the iron is ready to flow out it is drilled. The work of drilling through this clay is considerable, and in modern furnaces is done by a steam tapping hole drill.

Just above the throat is the bell O and hopper H (Fig. 1). The materials are placed in the hopper and dumped into the throat of the furnace, by lowering the bell. The bell is raised and lowered by levers and counter-weights, operated by steam or compressed air.

The gases leave the top of the furnace just below the bell at

N; they pass through a dust catcher and then go to the stoves and boilers to be used as fuel. The stoves are used to heat the air for the tuyeres, and the boilers furnish steam for the blowing engines and hoisting engines.

The columns M support the weight of the furnace. The whole rests on the masonry foundation. The space F, called the expansion space, allows for the expansion of the inner wall; it is sometimes packed with granulated slag.

MATERIALS.

The materials used in the blast furnace are:

Ores, already briefly described.

Fluxes. Flux is the substance added to combine with the earthy impurities and make a fusible slag which floats on the molten iron. The impurities which would soon clog up the furnace, are thus removed. Limestone and Dolomite are the usual fluxes. Oyster shells are used in Maryland on account of cheapness.

Fuels. The fuels used are coke, which is made in beehive ovens from soft coal; charcoal, which is wood charred in heaps or kilns; anthracite coal, and very rarely bituminous coal.

The fuel depends largely upon the locality. Charcoal is a good blast furnace fuel on account of its porosity, slight ash, and freedom from sulphur. Coke is the best fuel because it is strong enough to resist being crushed by the great weight of materials and because it burns rapidly thus giving a large output. Anthracite coal breaks up very fine and burns to CO slowly. A good mixture is $\frac{1}{4}$ coke and $\frac{3}{4}$ anthracite coal. Bituminous coal is rarely used as it cakes and absorbs heat.

OPERATION OR RUNNING.

Blowing in. - To start the blast furnace it is first thoroughly dried and then filled with cord wood to about half-way up the boshes. Upon this is placed a blank charge of coke, and then successive layers of fuel, flux and ore, with gradually increasing amounts of ore, until the regular charge is reached. The wood is then lighted and the hot blast of air turned on. At first this blast is under slight pressure. When coke is used the iron begins to flow in about 15 to 20 hours after lighting.

The ore, fuel and flux are brought to the scales in barrows called buggies. They are then weighed and wheeled to the elevator, and a certain number of barrows of each dumped into the hopper. In many large furnaces self-dumping cars are run to the top on an inclined railway, and the charging is entirely automatic. The fuel charge is usually dropped in by itself, followed by the ore and flux. The level of stock in the furnace is kept constant by regulating the charges. The temperature of the blast is kept as nearly constant as possible, being regulated by the admission of cold air. Cold water is kept running through the cooling rings around the bosh walls. Slag is either drawn off at intervals or continuously, and the molten iron which collects in the crucible, is drawn off every four to six hours by drilling the tap hole. It runs into channels formed in sand; the main channel is called the sow, and the smaller ones branching from it, the pigs. When solid the pigs are broken apart and stacked ready for transportation. The latest development in pig casting is an apparatus consisting of an endless iron mould which revolves and receives the charge and discharges the cooled pigs on the cars.

The furnace is run continuously day and night until it is necessary to shut down for repairs. Sometimes furnaces are run continuously for three to five years.

A good-sized blast furnace using coke as a fuel, will produce 300 tons of pig iron every twenty-four hours, and some of the largest can turn out 600 tons.

BANKING THE FURNACE.

It is sometimes necessary to shut down the furnace, because of a falling market, a flood, or a strike. If it is to be banked at a moment's notice, the first thing to do is to tap out the metal, shut off the blast and the water jackets; then close the furnace so that there will be no draft through the shaft. The tuyeres are blanked by ramming in clay balls. In this case the blast should be resumed in two or three weeks. If there is time to plan the shutting down, a large charge of fuel is dumped in and successive charges containing an increasing proportion of ore. The blast is shut off when the fuel reaches the tuyeres; the bell sealed and the cooling water decreased. The blast need not be resumed in this case for four or five months.

To blow out for repairs, stop the ore charges, and continue to charge fuel with a small amount of flux until the flow of metal ceases.

THE CHEMISTRY OF THE FURNACE.

In the blast furnace the oxides of iron give up their oxygen and become metallic iron. The most important substance for effecting this change is carbon monoxide CO. As we learned in Chemistry, CO gas has an affinity for oxygen, tending to form CO_2.

At the tuyeres the carbon burns to CO. Near the top of the furnace, at a temperature of 400° to 600° F, this CO reduces the iron ore (Fe_2O_3) to metallic iron, thus

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2.$$

The iron is not melted here, but is in a pasty condition. The charge gradually descends, getting hotter and hotter. At the boshes it is at a bright red heat, and in the lower part the iron begins to melt, and the lime, silica and other earthy materials fuse and form slag. At this point part of the silicon, manganese, sulphur and phosphorus are reduced, and together with a little carbon, combine with the iron. In the crucible all is melted and the temperature is above 2200° F.

SLAG.

The earthy materials, silica, alumina, and sulphur of the ore and fuel, combine with the flux, and form the slag. A large part of the sulphur is then eliminated from the ore; but none of the phosphorus. The quality of the iron depends largely on the composition of the slag. If a high lime slag is used in order to reduce the sulphur and silicon in the pig iron, there is danger that the slag may not run well, in which case more alumina is used. A good slag has approximately the following constituents: 52 per cent $CaO + MgO$, 16 per cent Al_2O_3 and 32 per cent SiO_2.

STOVES.

In the first blast furnaces cold air was used for the blast. Stoves were introduced to effect a saving of fuel and to increase the out-put. The waste gases from the blast furnace contain about 25 per cent of carbon monoxide, CO, and 1 per cent of hydrogen, H. These gases are burned with air in brick stoves and the fire brick flues are heated to redness. Then the cold air blast is run through and is heated to above 1000°F.

Four stoves are generally used in a set, three being heated while the fourth is giving out heat to the blast. The fuel consumption with a hot blast is about one-half that with a cold blast.

CAST IRON.

The iron produced by a blast furnace, known as cast iron or pig iron, is impure. It contains carbon, phosphorus, sulphur, silicon, manganese, and traces of other elements.

Cast iron is brittle, fusible and cannot be welded. It melts at a temperature of 2100°F. to 2300°F. Gray iron is more fluid when melted, and not as brittle as white iron.

Cast iron is suitable for castings because it expands at the moment of solidifying; this expansion is due to the change in the position of the crystals and results in a sharp impression of the mould. The casting is smaller than its pattern because the shrinkage in cooling from a red hot solid is greater than the expansion at the moment of solidification. If iron moulds are used, the surface of the casting becomes chilled, which causes a harder surface.

The Tensile Strength of cast iron is 13,000 — 29,000 pounds per square inch; Compressive Strength 82,000 — 145,000 pounds per square inch; Modulus of Elasticity 14,000,000 to 22,000,000.

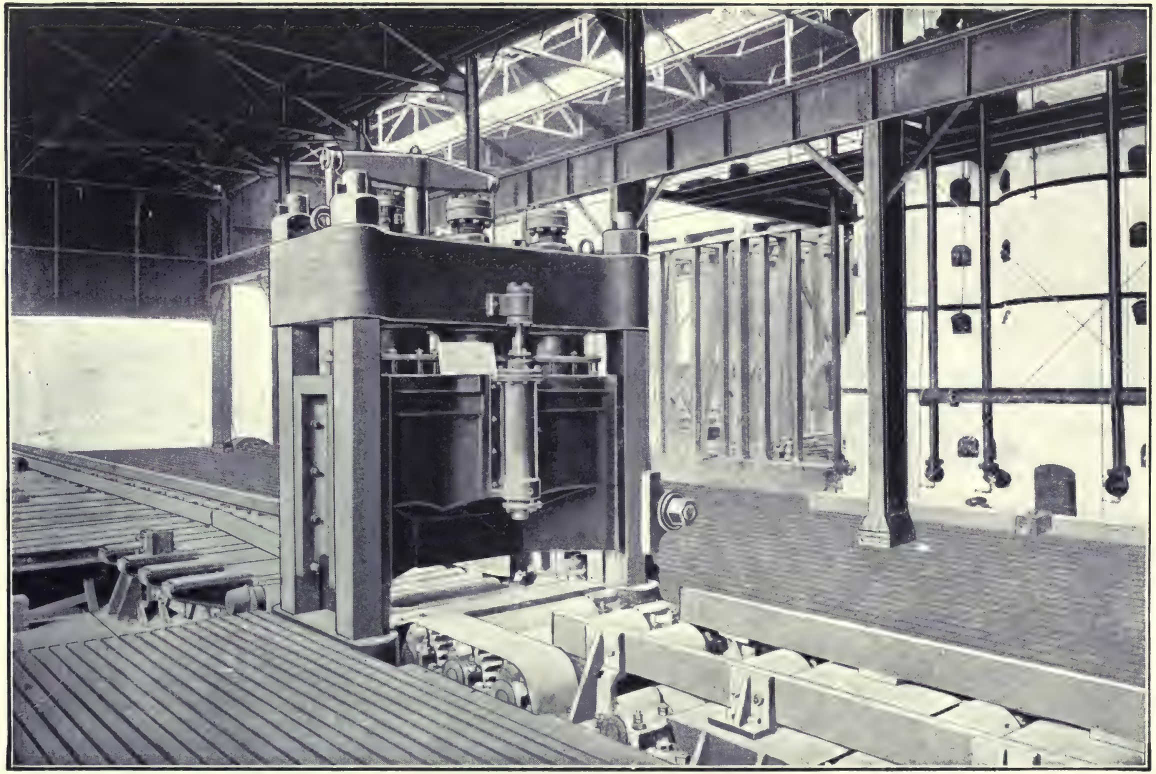
Pig Iron is sometimes graded according to its fracture. This method is satisfactory if the irons are made from uniform ores and mixture of fuels; but is unreliable if the irons are produced in different sections of the country, or from different ores. Grading by chemical analysis is better. There are five standard grades according to hardness.

No. 1. Gray. Fracture rough. It is dark, open grain and the softest grade. Used exclusively in foundry work. Tensile Strength low. Elastic Limit low. Turns soft and tough.

No. 2. Gray. Mixed grain. Harder than No. 1. Fracture less rough, with higher Tensile Strength and Elastic Limit than No. 1. Used in foundry. Turns harder, less tough and more brittle than No. 1.

No. 3. Gray. Close grain. Used in foundry and rolling mill. Turns harder and less tough than No. 2.

No. 4. Mottled. Dotted with small black dots of graphite. Little



HYDRAULIC BLOOM SHEAR.

The Wellman-Seaver-Morgan Co.

grain. Used in rolling mill. Lower Tensile Strength and Elastic Limit than No. 3.

No. 5. White, no grain, smooth fracture. Used in the Bessemer process and in the rolling mill. Tensile Strength and Elastic Limit lower than No. 4. Too hard to turn and very brittle.

The following table gives average analyses of the various grades of cast iron, the amounts being given as per cents:

Grade Number.	Iron.	Graphitic Carbon.	Combined Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
1	92.37	3.52	.13	2.44	1.25	.02	.28
2	92.31	2.99	.37	2.52	1.08	.02	.72
3	94.66	2.50	1.52	.72	.26	Trace	.34
4	94.48	2.02	1.98	.56	.19	.08	.67
5	94.68	——	3.83	.41	.04	.02	.98

INFLUENCE OF CARBON, SILICON, PHOSPHORUS, SULPHUR AND MANGANESE.

Carbon. The state of the carbon in the pig iron is a most important factor in the quality. If the carbon is combined with the iron in the form of an alloy, a hard, brittle, white iron is produced. If it is present mainly as graphite distributed as small crystals throughout the entire mass, the iron is soft and gray in color, but not as strong as white iron. Gray iron expands more on solidifying and contracts less in cooling than white iron.

Silicon. The amount of silicon and the rate of cooling determine the proportion of graphitic to combined carbon in the casting. Increasing the silicon in cast iron increases the proportion of graphitic carbon, thus making the iron softer. A large quantity of silicon renders the iron stiff and weak.

Phosphorus. Phosphorus in general weakens cast iron, but it is not harmful if less than 1 per cent is present. In some cases phosphorus is beneficial, as it decreases shrinkage and increases fluidity. For small, thin castings, iron may contain a little over 1 per cent phosphorus.

Sulphur. Sulphur makes castings hard and unsound. It also prevents the iron from flowing well. The amount of sulphur should not be over .5 per cent for sharp castings.

Manganese. Manganese in cast iron increases hardness and shrinkage and makes it more brittle. Manganese makes the iron capable of holding more carbon. Sometimes the amount of carbon is as high as 5 per cent, as in Spiegel.

Manganese with some chill is used in the foundry to produce hardness of surface. The magnetism of iron is decreased by manganese ; if 25 per cent is present all magnetism is lost.

CASTINGS.

In order to get a good casting, an iron having the following requisites should be used :

Shows gray fracture.
Is easily worked by tools.
Fills the mould to the thinnest parts.
Chills with a smooth surface.
Free from blow-holes.
Has moderate strength.
Little shrinkage.

An iron with the following constituents fills these conditions:

Carbon,	3½ per cent.
Silicon,	1½ per cent to 2 per cent.
Phosphorus,	not over .7 per cent.
Sulphur,	only a trace.
Manganese,	.35 per cent to .70 per cent.

For large castings lower the silicon. For increase in strength lower the carbon, silicon and avoid phosphorus. For resistance to chemical action make the manganese as high as brittleness will allow.

Silver-gray and ferro-silicon irons are used to increase silicon. Spiegel and ferro-manganese are used to increase manganese. Both wrought iron and steel scrap are used to reduce carbon.

MALLEABLE CAST IRON.

Malleable cast iron is a crude form of wrought iron obtained by decarbonization. The castings are made in the ordinary way from low silicon iron with little phosphorus and sulphur ; they are embedded in oxide of iron or peroxide of manganese and heated to a red heat until most of the carbon is removed from the surface. The time necessary for this operation is three to fourteen days, depending upon the size of the casting.

An analysis for good malleable iron is:

Si	.75 — 1.00 per cent.	P	.20 per cent.
S	below .05 per cent.	Mn	.40 to .75 per cent.

This wil be a No. 3 iron.

In making malleable castings, sharp angles and abrupt changes from heavy to light sections should be avoided. Several thin ribs in place of one thick rib should be used. As much surface as possible should be exposed, as the strength lies in the skin.

WROUGHT IRON.

Removing most of the carbon, silicon, phosphorus and manganese from pig iron makes it tough, malleable, harder to melt and capable of being welded. This iron is known as wrought iron, and is obtained by a process called puddling. The operation of making wrought iron from the ore is called a Direct Process. On account of its simplicity it was the first used.

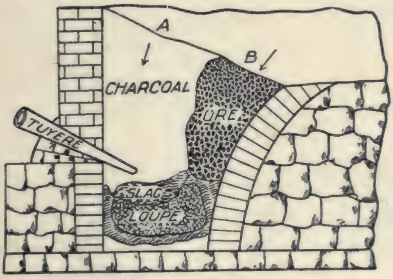


Fig. 2.

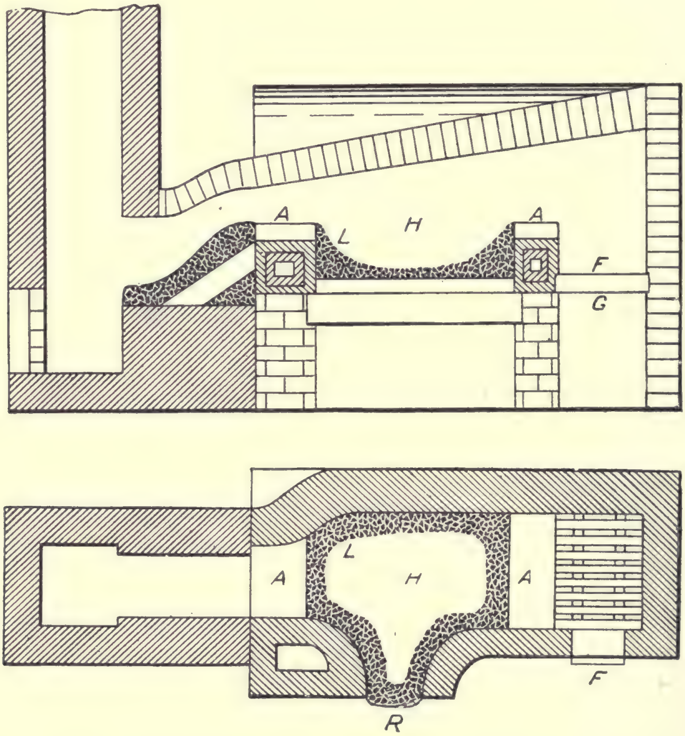
The Direct Processes are carried on at a low temperature; the production is small and variable, and about 20 per cent of the iron in the ore is lost. One of the oldest methods of making wrought iron directly from the ore is the Catalan Process. Ore of egg size is charged at B, Fig. 2, and charcoal at A. As the smelting progresses, charcoal and moist fine ore are charged at A. As the ore becomes reduced it works towards the tuyere; when it is all reduced it is taken out in a large lump called the "loupe" and worked under a hammer.

There are other processes, but they are unimportant and most all have been abandoned.

THE PUDDLING PROCESS.

The refining of pig iron by puddling converts it into wrought iron. This process is carried on in a reverberatory furnace. Fig. 3 shows sectional view of the plan and elevation.

The furnace has a low-arched roof and oval hearth H. The flame from the fire passes over the charge of iron, which is melted by the intense heat. The pig iron used in this process is gray and unrefined and has more silicon than white iron. The fettling or lining L of the hearth is made of good magnetite or hematite. The fettling is repaired after every heat.



A. — BRIDGES.
F. — FIRE-DOOR

Fig. 3.

G. — GRATE.
R. — RABBING-DOOR.

Carbon, silicon, manganese, phosphorus and sulphur unite with oxygen from the hot blast and the iron ore lining, thus reducing the molten metal to wrought iron. In order that the whole of the metal may come in contact with the fettling it is stirred constantly by rods called "rabbles." It takes about thirty minutes to melt down, and then carbon begins to be oxidized to

CO gas, which makes a violent boiling for about 15 minutes. The silicon, manganese, etc., oxidize and form a slag. When all the carbon is boiled out, bright points appear and the iron becomes pasty. The iron is gathered into balls and then worked under the hammer and rolls to expel the slag. It is afterward reheated and rolled between grooved rollers, which causes the particles to become close together. If the bar is rolled once it is called muck bar; if cut up, heated and rolled again, merchant bar ; the best bar iron is rolled a third time.

The Puddling Process and the manufacture of wrought iron is gradually giving way to mild steels ; but because of the small amount of slag it contains between the fibres, which acts as a flux, wrought iron welds much easier than steel and is preferred by blacksmiths.

The Puddling Process is expensive on account of the large amount of fuel used in the production of metal. About one ton of fuel is necessary to produce one ton of muck bar. For this reason and on account of the expense of the mechanical work of puddling, many efforts have been made to produce a cheaper and more simple process.

Boilers have been mounted over the furnace to utilize the waste gases as fuel, but on account of the fluctuating heat of the furnaces they have not been entirely successful. Water-tube boilers mounted in this way have been the most satisfactory.

There are several contrivances to save fuel and labor, but as the mechanism is likely to get out of order, they are not always reliable. For saving of labor, the Dank's Puddling Furnace, Fig. 4, is the most efficient and satisfactory of the mechanical puddlers. It is shaped like a short barrel, lying on its side. It is supported by friction rollers, two at each end, and driven by a large gear G around its middle. In this furnace the revolving of the hearth takes the place of puddling or stirring by hand.

Iron ore worked in layers at low heat forms the fettling. It is fed with molten iron from a furnace by means of a ladle. In some places this furnace is used for ordinary puddling, and in others for making wrought iron for the Open-hearth and Siemens Processes for making steel.

Wrought iron contains from .5 per cent carbon to only a trace; as carbon decreases, malleability increases, and the melting point rises. The melting point of good wrought iron is about 3000°F.

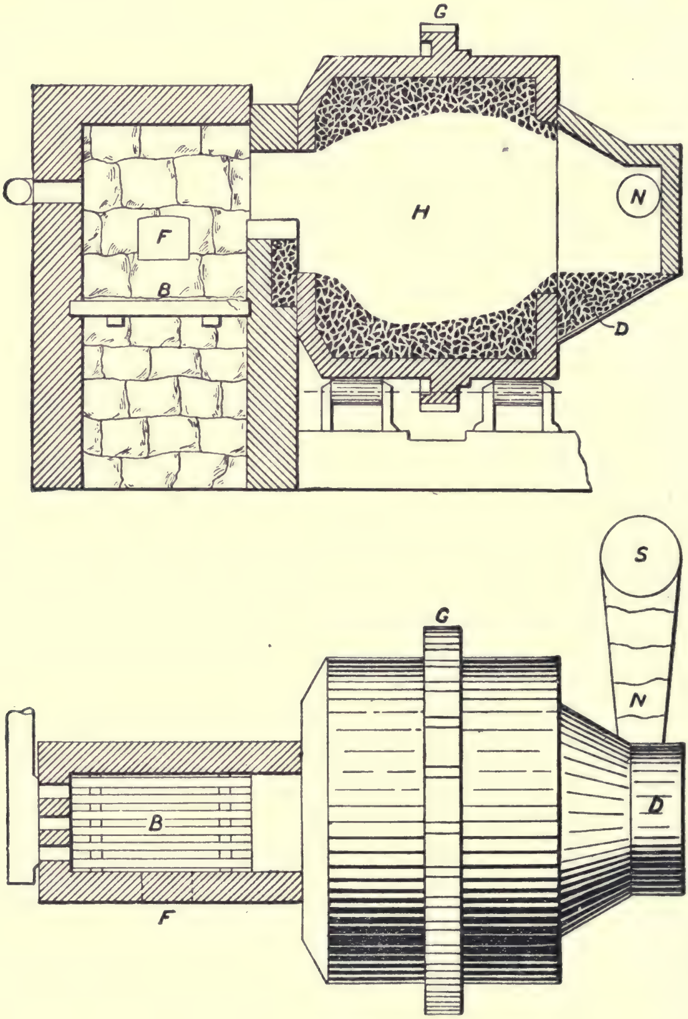


Fig. 4.

B—GRATE.
F—FIRE-DOOR.
H—HEARTH.
D—MOVABLE FLUE-PIECE.
N—FLUE TO STACK.
S—STACK.

Wrought iron contains about 2 per cent of slag distributed among the fibres. It is always present because the iron is finished in a pasty condition and the slag is never completely removed by the subsequent squeezing and rolling.

The fracture of wrought iron is coarsely fibrous, sometimes showing a few bright granular spots. The best iron is granular when broken suddenly.

The reduction of area of bars by rolling influences the strength and elastic limit. In general, the greater the reduction the higher the strength and elastic limit. Underheated bars have an unduly high tenacity and elastic limit.

The absolute strength of wrought iron is not materially altered by cold. The extensibility, or ductility, is not less in severe cold than at ordinary temperature. The modulus of elasticity rises as the temperature falls.

WELDING.

The process of welding consists of heating two pieces of iron to a high temperature, laying them together and hammering. Borax is sometimes sprinkled on the surfaces to be united, in order to keep them bright. This is accomplished by the union of borax with the oxide forming a fusible borate. In order that the form of the piece after welding may not be spoiled by hammering, the two ends to be joined are upset and scarfed. The upsetting makes the ends larger, so that they may be hammered without making the joint too small, and the scarfing roughens the ends, making the pieces join more easily.

STEEL.

CEMENTATION PROCESS.

Cement or blister steel is made from wrought iron by this simple process. The purest, soft wrought iron is heated to redness while completely covered with charcoal. The temperature is kept constant for over a week. The iron takes up some of the carbon from the charcoal and is converted into steel. It is called blister steel on account of its appearance, the surface being covered with small scales or blisters. These bars of blister steel are cut, heated and rolled together, forming shear steel. If the process is repeated, the product is called double shear steel.

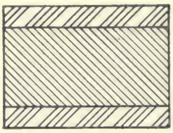
Blister steel that has been cut up, melted in a black-lead pot and cast in an ingot, is called cast or crucible steel.

The metal used in Sheffield, England, is wrought iron made from Swedish pig iron. Hammered wrought iron bars are laid in firestone pots in layers, surrounded with charcoal. At one end is placed a test bar, so arranged that it may be drawn out, examined, and returned. The temperature is gradually increased for 7 days to about 1150° F., and then the furnace is kept at this temperature for 7 or 8 days more. It takes 7 days for it to cool down.

When the bars are taken from the charcoal, the outside layers are converted into steel, leaving the center wrought iron. The use for which this steel is intended determines the amount of conversion; the various kinds are classified as follows:

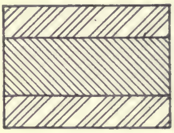
(1) Spring heat, .5 per cent C. Large iron center.

1



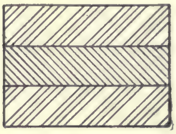
(2) Country heat, .63 per cent C. Smaller iron center.

2



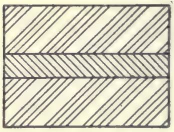
(3) Single shear heat, .75 per cent C. Equal iron and steel.

3



(4) Double shear heat, 1 per cent C. Mostly steel.

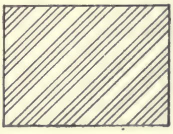
4



(5) Steel through heat, 1.25 per cent C. All steel.

(6) Melting heat, 1.5 per cent C. All steel.

5 AND 6



The reaction which takes place is

$$4Fe + 2CO = Fe_4C + CO_2.$$

CRUCIBLE PROCESS.

The materials are bar iron with charcoal, puddled bar or blister steel and charcoal. The crucibles are made of clay or graphite, with a capacity of 50 to 85 pounds. The charge is put into the crucible, and after melting is allowed to stand for a time, called the killing period, and then poured into moulds.

In American practice, graphite crucibles are used, which are made from a mixture of fire-clay and sand, and about 50 per cent graphite. This mixture is ground, allowed to stand for a few days, and is then moulded by being pressed into a wooden mould. When dry, it is baked in a kiln. These crucibles can be used about five times, if the successive charges are gradually diminished in amount.

The crucible is charged cold. The pieces of iron are surrounded with charcoal, with a little manganese, and sometimes a little salt or ferrocyanide of potassium mixed with it. This crucible, after being covered, is placed standing on the coal in a hot furnace. After three hours, during which the contents are melted, the cover is lifted, and the melter examines the charge to determine the length of the "killing" period. During this period, which is about 45 minutes, the metal is becoming tranquil and is taking silicon from the sand in the walls of the crucible. The silicon prevents blow-holes. At the right time and temperature the crucible is lifted out and the slag skimmed off. The metal is now ready for casting, or "teeming." This is done by pouring the metal into split moulds.

The ingots are graded and hammered into bars for different uses. Crucible steel furnishes the finest grades for cutlery and machine tools; it is superior to Bessemer and Open-hearth steel, because pure materials are used and the process is carried on in a closed vessel, thus protecting the metal from sulphur gases from the fuel.

It has low phosphorus, low sulphur, no iron oxide, less gases, high carbon and high silicon.

Crucible steels are graded as follows:

Razor. 1½ per cent C. Easily burned, very hard temper, welded with difficulty.

Saw-file. 1⅜ per cent C. Not easily burned, hard temper.

Tool. 1¼ per cent C. Not easily burned, hard temper, welded with difficulty.

Spindle. 1⅛ per cent C. Not easily burned, hard temper, welded with difficulty.

Chisel. 1 per cent C. Not easily burned, fair temper.

Set. ⅞ per cent C. Difficult to burn, little temper, easy to weld.

Die. ¾ per cent C. Difficult to burn, little temper, easy to weld.

THE BESSEMER PROCESS.

Bessemer, by his experiments, found that the temperature of molten metal was raised by blowing a current of air through it.

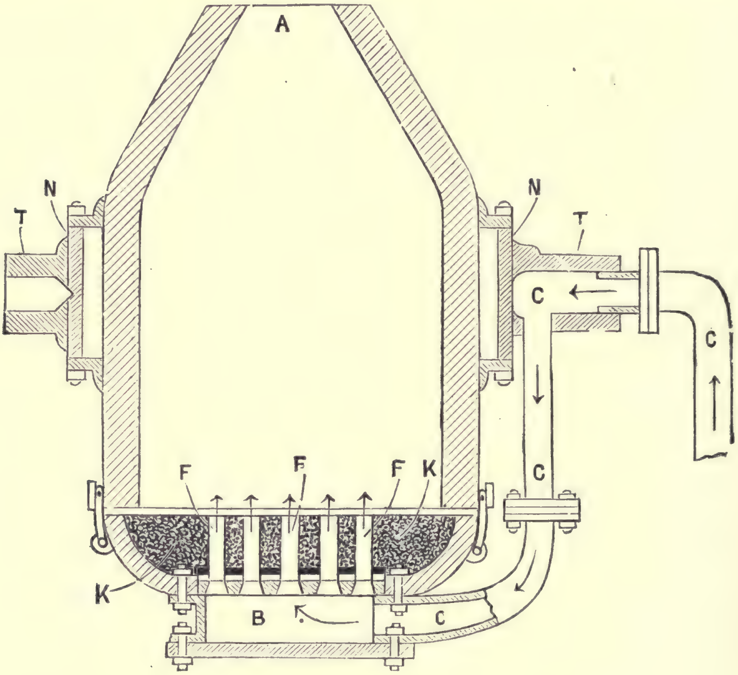


Fig. 5.

He tried to make wrought iron from pig iron, but found that the metal taken from the converter at that point was worthless; by restoring carbon by means of an alloy the product was better than wrought iron.

By this process steel is made from pig iron by burning out the foreign substances and replacing the necessary amounts of carbon, and manganese. These foreign substances — silicon, carbon and manganese — are burned out by blowing a blast of cold air through the molten pig. The desired amounts of carbon and manganese are replaced by mixing the proper proportion of spiegel with the molten pig.

The process is carried on, not in a furnace but in a vessel called a converter, in which molten pig is "converted" into steel.

There are several forms of converters. Fig. 5 shows a concentric converter. It is round, with a detachable flat bottom. The outer casing is of sheet iron. It is filled and emptied at the nose A. The current of cold air enters through the pipe C, and passes through the trunnion T. It enters the converter from the wind-box B, passing through the tuyeres F. The tuyeres are of fire brick 24 to 28 inches long, and have 19 holes $\frac{5}{16}$ inch in diameter, or 7 holes $\frac{3}{8}$ inch in diameter. The trunnion rings N are fastened to the converter, which turns on the trunnions T. The bottom is coupled on with clamps.

The pig iron is not melted in the converter, but poured into it in a molten state.

There are two processes of working.

(1.) The Acid Bessemer.

(2.) The Basic Bessemer, or Thomas-Gilchrist.

The difference is in the lining of the converter. If this lining is acid (siliceous) no phosphorus or sulphur is burned out of the pig. Only irons with small amounts of these elements can be used in this process. If the lining is of lime or magnesia all the phosphorus and almost all of the sulphur can be burned out. Only a high phosphorus pig can be used in the basic process, as the heat needed to keep the steel liquid, during casting, is obtained from the phosphorus.

The Basic Process is used in Germany with good results.

In both processes the carbon, silicon, manganese, etc., are oxidized, leaving the molten iron in a condition similar to that of wrought iron. The carbon passes away as CO, and the oxides of silicon and manganese with a little iron oxide form a slag. Molten spiegel is added to give it the necessary carbon, and a little manganese to make it malleable. The molten pig is obtained in two ways; by melting the pig in cupolas, called the Cupola Process; and by taking the iron from the blast furnace, called the Direct Process.

THE CUPOLA PROCESS.

Pig iron, from piles which have been sampled and analyzed, is loaded into trucks and wheeled to the cupolas. The composition of this mixture is about as follows :

Silicon	1.75 per cent.
Manganese	.75 per cent.
Sulphur less than	.05 per cent.
Phosphorus less than	.10 per cent.
Copper less than	.10 per cent.

This is weighed, hoisted to the cupola and dumped in. Spiegel is sampled, analyzed and melted down in smaller cupolas. The fires in the cupola are started with wood upon which is placed coke; the charges of pig iron being dumped on the coke. It takes about two hours to melt the first charge. As some silicon burns out in the cupola the percentage is reduced. When the iron goes into the converter there must be from 1 to 2 per cent silicon present, depending on the temperature of the iron.

THE DIRECT PROCESS.

In the ordinary blast furnace, different casts differ too much in silicon and sulphur to allow taking the metal as it flows from the furnaces into the ladle and then to the converter. Therefore, it is first poured into large reservoirs or mixers, in which the casts from the different furnaces are mixed. In Sweden, however, the product from a number of small charcoal furnaces is regular enough for the iron to be used directly. The iron is taken from the mixers as wanted and used as cupola iron. If the iron stands in the mixer a long time some sulphur is eliminated, but no carbon or silicon. To prevent the iron from chilling on top, a jet of oil is sprayed over it. As the temperature of direct iron is greater than that of cupola iron, less silicon is needed.

Blowing. The heated bottom is coupled on and the joint rammed tight from the outside. When the lining is made yellow-hot by means of a fire of wood and coal with a gentle blast, the iron from the cupola or the mixer is poured in and the blast turned on.

The converter is turned up to a vertical position, as shown in Fig. 6, as it is filled when turned down on its side. The blast rushes up through the bath, and silicon begins to oxidize raising the temperature high enough for the carbon to burn. Carbon burns to CO. The blower judges whether there will be enough heat to keep the steel liquid during the casting, by the appearance of the flame which comes out of the throat of the converter. If he thinks there will not be enough heat, the converter is turned half-way down and the CO burns to CO_2. Fig. 7 shows the converter turned down until the tuyeres are exposed.

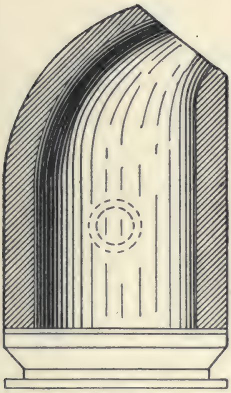


Fig. 6.

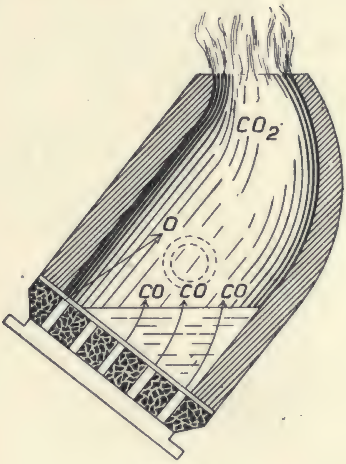


Fig. 7.

In case there is too much silicon for good working, or if the charge is too hot, cold steel scrap is dropped into the nose of the converter from a platform above. The scrap, being free from silicon, reduces the percentage of silicon in the converter. If the steel is made too hot it will not roll well. Sometimes a jet of steam is admitted to the blast pipe to cool down a charge. The carbon is reduced to about .05 per cent after about 12 minutes blowing under a pressure of 30 pounds per square inch. This is shown by a shorter flame. An instant later the flame becomes fringed with brown smoke which is Fe_2O_3. The converter is now ready for the spiegel. The spiegel contains about 20 per cent manganese and 4.5 per cent carbon. If hard steel is being made, spiegel is used, but if it is to be soft, which requires some manganese and but little carbon, ferro-manganese is used instead of spiegel. This has 80 per cent manganese and 6.5 per cent carbon. The amount of molten spiegel added is about 10 per cent of the weight of the converter charge, and of ferro-manganese from 1 per cent to .8 per cent. The ferro-manganese is not remelted but shoveled red hot in pieces the size of an egg into the casting ladle. After the steel has been poured out into the ladle most of the slag remains in the converter. It is dumped into a car beneath by tipping the converter bottom up. This loss or waste is from 10 per cent to 12 per cent.

The charge varies from 5 tons in a small converter to 20 tons in a large one, and a new charge is blown every twenty minutes. The bottoms of the converters are examined and any bad tuyeres are plugged with plumbago mud and blanked. The life of one of these bottoms varies from 18 to 25 "blows." The conditions which injure the bottom are low blast, a great depth of metal above the tuyeres, too much Al_2O_3 and Fe_2O_3 in the ganister mixture, and dampness of the repairing material. The bottoms are dried four days in a drying oven; several of these are always kept on hand drying, for if not absolutely dry, they are useless.

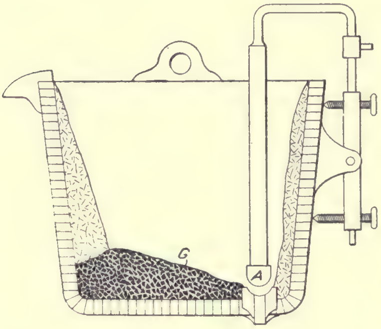


Fig. 8.

"Acid" Converter Lining. Converters are lined with blocks of ganister with the joints faced with ganister mud. If pure ganister is used it is likely to give trouble on account of its expansion under heat. Too much Al_2O_3 causes the lining to melt out rapidly. The bottom is lined with a mixture of ground ganister and fire clay. Ganister, a flinty sandstone, is composed of about 98 per cent of SiO_2 with about 1 per cent or 2 per cent of $Fe_2O_3 + Al_2O_3$. The fire clay has about 86 per cent of SiO_2, 10 per cent Al_2O_3 and 4 per cent of alkalies. If the manganese in the pig iron is less than $1\frac{1}{2}$ per cent the linings last for months. A high lime slag in the pig will rapidly flux the SiO_2 of the lining. The nose section is lined with brick or stone and lasts but a short time.

The Casting Ladle. The general shape and arrangement of the casting ladle is shown in Fig. 8. The shell is made of iron plate and is lined with a layer of brick and upon this is pounded moist loam. The bottom G is made of rammed ganister material. The pouring hole is fitted with a cylindrical brick nozzle, with a hole 2 to 4 inches in diameter. The stopper A sets upon a bowl shaped seat. The stopper and stopper slide are shown in the figure. The end of this stopper, which fits the seat, is made of plumbago. The lining of the casting ladle lasts about 40 blows. A new nozzle and stopper is put in about every fourth blow.

Moulds. The moulds must be hard enough to withstand the strain caused by expansion and contraction when heated or cooled, yet not brittle. These moulds, if made of iron have a composition as follows:

Silicon	1.7 per cent
Phosphorus	.1 per cent
Manganese	.75 per cent

Moulds are made of gray iron as white iron is too brittle These moulds last about 90 operations.

INGOTS.

Method of Pouring. Great care is necessary in the pouring of ingots. They should be poured in such a manner as to prevent spattering, oxidation of the surface and injury to the mould. There are three principal methods: Top pouring, the most natural, bottom pouring, and a combination of top and bottom pouring. The greatest objection to ordinary top pouring is that of spattering and oxidation of the surface. These are partly overcome by the admission of the molten metal through a pipe which reaches nearly to the bottom of the mould. By mechanical means, this pipe slowly recedes, so that the distance between its end and the surface of the metal is nearly constant. If the mould is bottom poured, the metal at the bottom, being kept hot, has a tendency to thin the bottom and walls of the mould. If they become too thin they are likely to crack or burst. The slag has to rise through the entire column of metal and if this becomes cooled particles of slag become entangled. Also, the slag has a tendency to solidify in the pipe by which the metal is introduced, thus causing poor ingots. The best results have been obtained from a combination of top and bottom pouring. During the first half of the time the metal is bottom poured and then finished by top pouring. In this case, the gases and slag have only a short distance to rise.

Shape of Ingots. Ingots are usually square with rounded corners slightly tapered to one end, so that they may be easily removed from the mould.

Gases and slag rise to the top of the ingot. Sometimes a "pipe" is formed in the center by the metal solidifying and shrinking away from the center. To prevent this the top is kept liquid longer by a covering of sand. It is advantageous to keep the cavity near the top, so that a large portion of the ingot will be sound. Another method is to cast ingots one on top of the other in a column, pouring one as soon as the preceding one has begun to solidify. This brings the cavity and imperfections in the last ingot. Another remedy is to cast the ingots longer than is necessary and cut off the top; but this is a waste of metal for the cut off portion has to be remelted and recast. Another way is to make the top rounding, in order to allow the impurities and gases to collect in the rounded part.

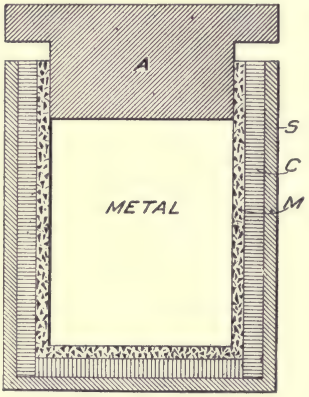
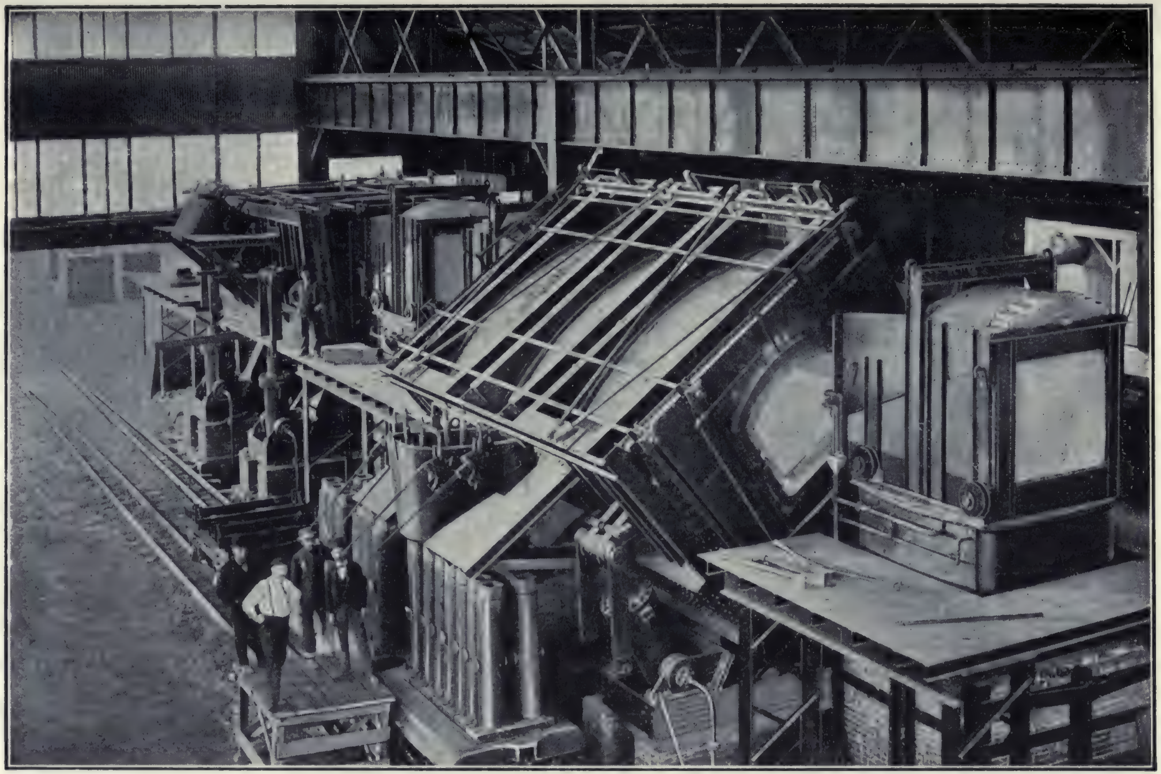


Fig. 9.

We learn from Chemistry that the solubility of gases in liquids increases with pressure; this principle is made use of in the casting of ingots. The mould is arranged as in the accompanying diagram, Fig. 9. The outside S is formed of steel in which is a thin layer C of perforated cast iron, the mould being lined with moulding sand M. The top plunger A is stationary. The mould is made to rise by powerful machinery. When the metal has begun to solidify the mould is raised until the pressure



ROLLING OPEN-HEARTH FURNACES
at Hamilton Steel and Iron Co.
The Wellman-Seaver-Morgan Co.

becomes 10 to 20 tons per square inch; this pressure is kept on for about 20 minutes. The gases are not squeezed out by this process; the pressure tends to dissolve them. This process is used in making armour plate and gun tubes, but is too expensive for ordinary use.

Rail Making. Very soon after an ingot is poured it commences to solidify at the surface. A solid shell forms with a pasty or liquid interior. As the ingot cannot be rolled until it has become of uniform softness it is put in a "soaking pit." By means of currents of hot gases, the ingot soaks or equalizes, that is, it becomes uniform throughout. It soaks in these hot gases for about an hour. The ingot is taken from the soaking pit by an electric traveller, and is rolled down in the blooming mill to a "bloom" of about 7 inches by 7 inches in section, which, after the ragged edges have been cut off by hydraulic or steam shears, is finished, without re-heating, in a rail mill. Sometimes the bloom is allowed to partially cool and is then reheated before being finished. This process is expensive on account of the fuel and labor, but it reduces the number of defective rails. The whole ingot is rolled in the rail mill into one long rail, and this is cut into standard lengths by hot saws. After the rails cool they are straightened in steam presses and are then inspected and bolt holes drilled in the ends. Steel rails have the following composition:

Carbon,	.40 per cent to .6 per cent
Phosphorus,	.08 per cent to .1 per cent
Manganese,	.75 per cent to .9 per cent
Sulphur,	.05 per cent to .1 per cent
Silicon,	.05 per cent to .15 per cent
and sometimes Copper,	.01 per cent to .2 per cent

If the carbon is above .6 per cent the rail will be too brittle and will break under the drop test. In this test a heavy weight is allowed to fall through a specified distance on a piece of rail about 3 feet long, supported at the ends.

If the carbon is below .4 per cent the rail is too soft to stand the wear of the car wheels; if the phosphorous is above .1 per cent the steel will be "cold short" (brittle); if the manganese is much below .75 per cent the ingot will crack in rolling; if the sulphur is above .1 per cent there will be short feathery cracks in the ingot when rolled, especially if rolled at a low red heat. Silicon up to .15 per cent improves the rolling qualities of the steel, but makes the steel brittle if the percentage of silicon is much higher.

The Bessemer process is also used in making soft steel. This steel is made into barbed wire, wire nails, hoop iron and sheets for tin plate and galvanized iron; it is also used for some structural steels and agricultural implements. This steel has about .1 per cent to .15 per cent carbon, and .4 per cent to .5 per cent manganese.

About 70 per cent of the steel made in the United States is Bessemer steel, and about 30 per cent of this is made into rails.

THE OPEN HEARTH PROCESS.

The Open Hearth Process for making steel is divided into three methods, according to the character of the material used. They are,

1, The Martin Process, in which pig iron and scrap are used.

2, The Siemens Process, or "pig and ore" in which pig iron and ore are used.

3, The Combination Process, using pig iron, scrap and iron ore.

The open hearth process was made possible by the invention by Siemens of the regenerative chambers, first successfully used by Martin, and is often called the Siemens and Martin process. The fuel is gas, which is burned on the hearth of a large reverberatory furnace. Both the gas and air are heated by the products of combustion in the regenerative chambers, as represented by Fig. 10. The heated gas and air enter the furnace on the left, burn on hearth H, and the products of combustion pass out and down through the chambers A and G on the right. These chambers are filled with fire brick set up with spaces between, called checker work, which becomes heated to a white heat. After a time the currents of gas and air are reversed and pass through the checker work just heated, becoming highly heated before they combine and burn, thus the heat is "regenerated."

The currents are reversed once every half-hour (to an hour)

1850 HORSE POWER WHEELER BOILERS
Stewart Iron Company

and a very intense heat is maintained so that the metal in the condition of wrought iron is kept in a molten state.

In this country the combination process is generally used. With this process the scrap and pig iron are first melted. As this iron contains too much carbon, iron ore is added to reduce the percentage. This process, like the Bessemer, has two main divisions, the Acid and the Basic open-hearth processes, having siliceous and lime-magnesia linings respectively, and like the Bessemer process, only low phosphorous iron can be used with the acid lining while high phosphorous stock is used with the lime lining. In the Bessemer process only medium and low carbon steels can be made, while in the open-hearth, steel of any grade of carbon can be made. This process also has the advantage of being more under control, and the product is more uniform, more reliable and contains less gas. Open-hearth steel costs about $2.00 a ton more than Bessemer.

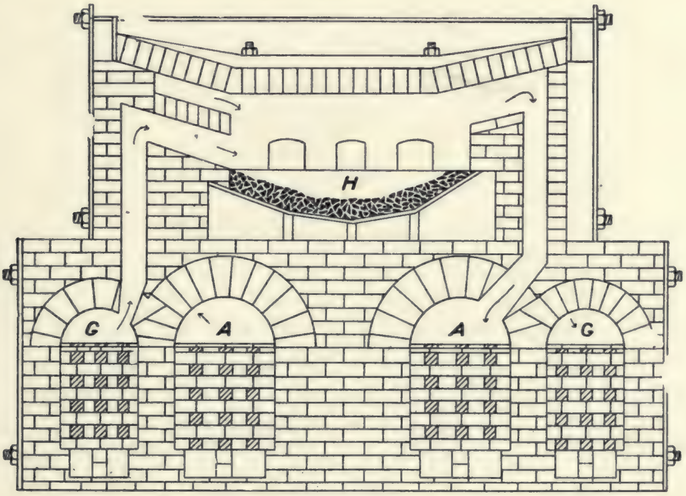


Fig. 10.

Open-hearth steel is used for making spring steel (carbon .8 per cent to 1 per cent) for cars and wagons ; structural steel for bridges and buildings ; steel for agricultural implements and tools ; cast steel and mild steel (low carbon) for boiler plates (carbon .15 per cent, and phosphorus .03 per cent).

The Bessemer process and open-hearth process can be advantageously carried on together, as the scrap and "crop ends" of the Bessemer are largely used in the open-hearth.

MANAGEMENT, OR RUNNING THE ACID PROCESS.

At the start the furnace is heated by a wood fire, and then the gas is turned on and lighted. When the temperature is sufficiently high to melt steel, the charge is put in. It consists of one-third pig iron, and the rest wrought iron and steel scrap. On account of the low melting point of pig iron, one-half of the pig iron is put in first on the bottom. If steel or wrought iron were charged first, it would be slow in melting. The scrap is then put on and covered by the rest of the pig, and currents of air and gas are reversed at intervals, each time coming up hotter. In four hours it is all melted, but the carbon is too high, and it is not yet ready for casting. To expel this carbon small amounts of iron ore are added. CO is produced, which boils off.

$$Fe_2O_3 + 3C = 3CO + 2Fe.$$

This boiling continues until the desired percentage of carbon is reached, which is determined by sampling. These samples are taken out at intervals, cooled and broken ; the percentage of carbon being judged by the appearance of the fracture. As the boiling down occupies three or four hours, there is time for an approximate chemical analysis. Manganese and silicon have both been absorbed by the slag, therefore some manganese must be added before casting. This is done by adding to the casting-ladle red-hot spiegel, or ferro-manganese, the size of peas. If steel castings are being made, a little silicon must also be added, to prevent blow-holes. When the steel is ready chemically, it is usually hot enough to cast. The furnace is tapped by driving a bar through the tap-hole, and the molten metal flows out of it into the casting-ladle, which is similar to that of the Bessemer process. The casting is done in moulds, as in the Bessemer process. Bottom pouring is often employed, especially if the ingot is to be made into steel plate. The bottom of the mould has to be repaired after each operation.

MANAGEMENT OR RUNNING THE BASIC PROCESS.

The furnace used is very similar to that of the acid process, except for the lining, which is of dolomite or magnesite. Dolomite is hard-burned lime made from a magnesia limestone. Magnesite is made from $MgCO_3$, calcined several times at high heat. Layers of dolomite or magnesite, mixed with 10 per cent of boiled tar, is rammed in with hot rammers all over the bottom and sides, above the slag line. Upon this hearth, scrap and high phosphorous pig iron are melted down. To prevent fluxing of the lime lining, limestone is spread over the bottom before charging. After melting there is too much phosphorus and carbon in the charge. These elements are oxidized by the addition of the iron ore. The agitation and boiling of the phosphoric bath is caused by the escaping gas, CO, and the metal is thus brought in contact with the basic slag and the phosphorus removed. If all the phosphorus is not out at this point, pig iron is added to raise the percentage of the carbon, and the bath is again boiled down. The appearance of the fracture of the sample indicates the amount of phosphorus present. If there is a large amount, two cross-lines of bright crystals, called the "Phosphorus Cross," appear in the center. The casting is the same as in the Bessemer process. The wear of the basic lining is greater than that of the acid, especially if the silicon is high. Holes in the hearth are repaired after each heat.

The tap-hole is rammed with tar dolomite or magnesite.

In an ordinary open-hearth furnace only two heats can be made in a day. The charge varies from 10 tons in a small furnace to 50 tons in a large one.

Tilting furnaces are being used in modern plants, which lessen the time of charging and working, and "direct metal" from mixers is used in place of pig, which further reduces the time. Altogether, the open-hearth process is gaining in favor in this country. The basic process is more used than the acid, because high phosphorous pig is cheaper.

GAS PRODUCERS.

Gas is the fuel used in the open-hearth process. The Siemens Gas Producer is now little used, most gas being made by the

Wellman Gas Producer. Fig. 11 is the sectional view of this producer. A forced draft, usually a steam-jet injector, supplies steam and air to the furnace under slight pressure. The following reactions take place when air or steam unite with coal:

$$C + O_2 = CO_2$$
$$CO_2 + C = 2\,CO$$
$$H_2O + C = CO + 2\,H$$

The resulting producer gas has about the following composition:

Nitrogen,	60.3 per cent
Carbon Monoxide,	22.8 per cent
Carbon Dioxide,	5.2 per cent
Oxygen,	0.4 per cent
Hydrogen,	8.5 per cent
Hydrocarbons,	2.8 per cent

In running the producer, there is a heat loss of about 35 per cent, principally in radiation, ashes, latent heat, decomposition of steam, and sensible heat of gas. Another producer, the Taylor Producer, has in place of the grate-bars a revolving dome-shaped plate, through which air is driven into the center of the fire. In place of the brick lining this producer has a water-jacket. Bituminous coal is the fuel generally used in these producers. As this gas contains about 60 per cent nitrogen, it is weak fuel. In a few localities natural gas, a stronger fuel, is obtained. A gas made of vaporized petroleum mixed with dry steam and forced through a red-hot metallic retort, is used in the Archer process.

SPECIAL STEELS.

Nickel Steel. Nickel steel is made by adding metallic nickel, nickel ore, or ferro-nickel, to the bath of the open-hearth process. The nickel increases its density, elasticity and strength. This steel is used for armour plate, on account of these qualities, and also because it does not corrode. Nickel steel contains about 4 per cent nickel, .3 per cent carbon, .7 per cent manganese, and .02 per cent phosphorus. For such uses as bicycle tubes, shafts, axles, etc., the high elastic limit of nickel steel tends to prolong indefinitely the life of the piece, and because of its superior toughness, offers greater resistance to sudden strains and shocks.

Aluminum Steel. From .05 per cent to .1 per cent aluminum in steel castings reduces the melting point, prevents blowholes, and keeps the metal liquid while being poured. Aluminum gives no increase of hardness.

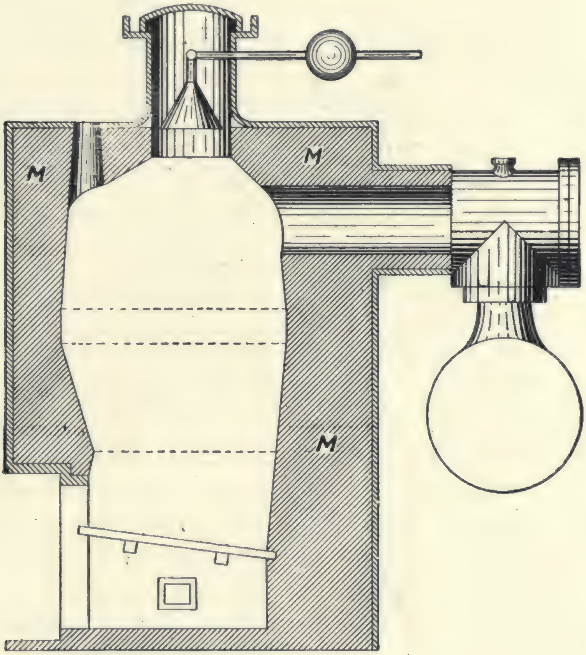


Fig. 11.

Chrome Steel. If chromite is melted in brasque crucibles with charcoal, the result, ferro-chrome, which has 40 per cent chrome and 48 per cent iron, is used in making chrome steel, by melting it with bar iron in crucibles. Chrome, like manganese, hardens iron. It also makes it more forgeable. It is used, on account of its hardness, for burglar-proof safes, but it is not entirely satisfactory, and other steels are fast driving it out. It has about the following composition: chromium, .5 per cent to 3 per cent; carbon, .5 per cent to .9 per cent.

Manganese Steel. Manganese steel is an alloy of iron and manganese, containing a considerable proportion of carbon. It there is a very small portion of manganese, the effect is slight. As the proportion of manganese rises above 2.5 per cent the strength and ductility diminish, while the hardness increases. This hardening effect is a maximum with about 6 per cent manganese. Above this the strength and ductility both increase, and at 14 per cent of manganese the metal is so hard that it is difficult to cut with steel tools. It welds with great difficulty, but it can be forged. Its toughness increases by quenching from a yellow heat. It has a remarkable combination of great hardness, which cannot be lessened by annealing, great tensile strength, toughness and ductility. The fact that it cannot be machined, on account of its hardness, limits its usefulness. It is used principally for car-wheels, dies and crusher-jaws.

Tungsten Steel. Steel containing a little carbon and tungsten is much harder than steel with carbon alone, and yet not very brittle. A specimen from Sheffield, England, for chisels, used untempered to turn chilled rolls, was not brittle, yet it was hard enough to scratch glass. It contained 9.3 per cent tungsten, .7 per cent silver and .6 per cent carbon. In working this metal it has to be given its final shape by hammering at red heat, and if the percentage of tungsten is high it is necessary to reheat it while it is being hammered. After the desired shape is reached the hammering must be continued, with numerous blows, until it becomes nearly cold. Tungsten is employed to produce steel of moderate hardness, with great toughness, resistance and ductility. Its principal use is for cutting-tools. It is self-hardening.

CASE-HARDENING.

By the process called case-hardening, a thin layer of steel is formed over the iron. To do this, iron is heated to redness, and powdered potassic ferro-cyanide $K_4Fe\,(C\,N)_6$, is sprinkled over the surface. When suddenly cooled, the surface of the iron is hard enough to resist a file. The chemical reaction which takes place is

$$K_4Fe\,(C\,N)_6 = 4\,KCN + FeC_2 + N_2.$$

THE HARVEY PROCESS.

The Harvey process for making armor plate is somewhat like case-hardening. The outside of the heated steel plate is covered with charcoal, from which it absorbs carbon in the same manner as wrought iron absorbs carbon in making cement steel. The layer of hard steel thus formed is further hardened by quenching with water. This makes a plate with an exceedingly hard surface, which breaks up shot and shell. The backing is, however, tough, mild steel.

THE EFFECTS OF THE ELEMENTS IN STEEL.

The following from Howes' Metallurgy of Steel will give an idea of the effects of the elements:

Carbon. Carbon up to 1.5 per cent increases Tensile Strength, Compressive Strength, and raises the Elastic Limit; decreases the malleability and welding power.

Silicon. Silicon increases hardness, Tensile Strength and solidity, and prevents blow-holes. Too much silicon makes steel brittle. From .3 per cent to .5 per cent should be the maximum.

Sulphur. Sulphur causes hot shortness; that is, the metal is brittle when hot, both under the hammer and rolls.

Arsenic has the same effects as sulphur.

Phosphorus causes cold shortness. It makes steel hard and liable to break. It increases the Elastic Limit and reduces Elongation.

Manganese prevents hot shortness and blow-holes, removes or offsets the effect of sulphur. It increases Toughness, Elongation and Tensile Strength. Too much manganese makes steel brittle when cold, especially after quenching.

Copper. Copper causes red shortness; .5 per cent may be allowed in rails, but 2 per cent makes steel worthless. Tin steels are not forgeable or ductile, either hot or cold.

TEMPERING.

Tempering steel is the process of giving it, after it has been shaped, the necessary hardness to do its work. A piece of steel after it has been properly tempered should be finer in grain than the bar from which it was made.

This is accomplished by first hardening the piece, usually harder than necessary, and then toughening it by slowly heating and gradually softening, until it is just right for the work. The process is as follows: The tool to be tempered is heated to a cherry red, and plunged into cold water or oil to a depth somewhat above the cutting edge. When this portion has become entirely cold, the piece is taken out and the cold end polished, usually with emery-cloth; the point is now too hard and brittle. The heat contained in the hot portion gradually enters by conductivity into the quenched part, and as it does so, colors are formed which denote temperature. The colors seen in order are pale yellow, straw, brownish yellow, light purple, dark purple, blue. They are formed by oxide on the surface. These colors run from the hot portion to the cutting edge, and when the proper color reaches the cutting edge, the whole piece is quenched. Some tools are of such a shape that the temper must be "drawn" to the desired color by reheating the piece between hot plates or in a hot iron ring.

The following list will give some idea of the colors, temperature and hardness of tools:

Very pale Yellow, temperature about 430° F.	Steel-engraving Tools. Turning Tools. Hammer Faces. Planer Tools. Wood-engraving Tools.
Straw Yellow, temperature about 460° F.	Dies. Taps. Drills. Punches. Reamers.
Brown Yellow, temperature about 500° F.	Gouges. Plane Irons. Twist Drills. Cooper Tools. Wood-boring Cutters.
Light Purple, temperature about 530° F.	Augers. Surgical Instruments. Cold Chisels. Edging Cutters.
Dark Purple, temperature about 550° F.	Axes. Gimlets. Needles. Hack Saws. Screwdrivers. Springs. Wood Saws.

COPPER.

As copper occurs in the metallic state, it was one of the earliest known metals. The native copper deposits of the Lake Superior region were worked by prehistoric inhabitants. Copper compounded with tin was the metal of the Bronze Age. With the exception of iron, copper is our most useful and important metal.

ORES.

The native copper of Lake Superior is still an important source of supply, but by far the largest quantity is obtained from the sulphide ores, of which Copper Pyrites ($Cu_2 S. Fe_2 S_3$) is the most important. When pure it contains 34.6 per cent of copper, 30.57 per cent iron and 34.9 per cent sulphur, but the average ore carries only about 12 per cent of copper. Spanish iron pyrites is another source of supply; it is first used in the manufacture of sulphuric acid, after which the copper is extracted from the "cinder." It contains only 3 or 4 per cent of copper, but carries also a small proportion of gold and silver, which makes it a profitable ore.

Carbonate ores, formed by the weathering of the sulphides are now about exhausted, as they occur only a short distance below the surface.

EXTRACTION.

There are two main processes for extracting copper from its ores:

(1) Process involving fusion.

(2) Wet process used for low-grade ores.

The most important fusion method is the "Welch" or "Reaction" process. The prepared sulphide ore is first roasted in heaps, kilns or a reverberatory furnace. Care is taken that not too much of the sulphur is expelled. Next, this calcined ore is fused in a reverberatory furnace. The copper has a greater affinity for the remaining sulphur than any of the other metals, and copper sulphide is formed.

$$Cu_2O + FeS = Cu_2S + FeO.$$

The ferrous oxide (FeO) and the silica unite and form a slag, which carries away lime or other impurities present. The cuprous sulphide Cu_2S combines with the excess of iron sulphide left in the charge, forming a fusible substance called a "regulus," or first copper matte, which contains about 30 per cent of copper. This first matte is again roasted and fused, and part of the iron slagged away as before, leaving the second matte, which contains about 50 per cent, if "blue metal" is wanted, or 75 per cent of copper, if "white metal" is being made. A small amount of metallic copper is also produced. These copper bottoms contain most of the impurities, including much of the gold and silver.

In a third reverberatory furnace the second matte is again partly oxidized and then fused, the product this time being crude metallic copper and a slag rich in copper. The rich slags from the first and second matte are worked up for their copper. The reactions by which metallic copper is produced are:

(1) $2Cu_2O + Cu_2S = 6Cu + SO_2$

(2) $3Cu_2O + FeS = 6Cu + FeO + SO_2$

The SO_2 gas passes away and the FeO goes into the slag.

Producer gas is used for heating the furnaces in modern plants.

CUPOLA SMELTING.

In the first stages of this process the chemical action is about the same as the "Welch" method. A first and second "Matte" is produced in small water-jacketed blast furnaces of rectangular sections using cold blast. (See Fig. 12.) Some "black copper" is produced with the second matte.

The second matte, called "white metal," is now completely roasted to oxide. This oxide of copper is reduced to metallic copper in a blast furnace by CO gas in the same manner as in the production of iron.

The reaction is

$$Cu_2O + CO = 2Cu + CO_2$$

The fuel is coke or charcoal. The slag from the first matte is thrown away, but the other slags go back into the process.

Less skilled labor is necessary in the cupola method and less fuel is required. It is consequently in favor in remote regions. The metal of oxidized ores (carbonates) can be extracted by this process in one operation. The reverberatory method produces purer copper, and must be used when there is much antimony and arsenic in the ore. Highly refractory ores, which are difficult to fuse in a blast furnace, can be better treated in reverberatories, as the slag can be skimmed off in a partly melted condition.

The variations in the foregoing processes are numerous. A common American practice is to use the cupola for obtaining the first matte, and finish the process in reverberatory furnaces.

Modified Bessemer converters are now successfully used to convert copper matte into crude copper. The converter has the tuyeres in the sides, and is lined with silica and clay. As the wear on the lining is very great, provision is made for quickly replacing a worn-out converter by one which has been relined. Mattes containing from 30 to 60 per cent copper have been thus successfully treated at a considerable saving of expense.

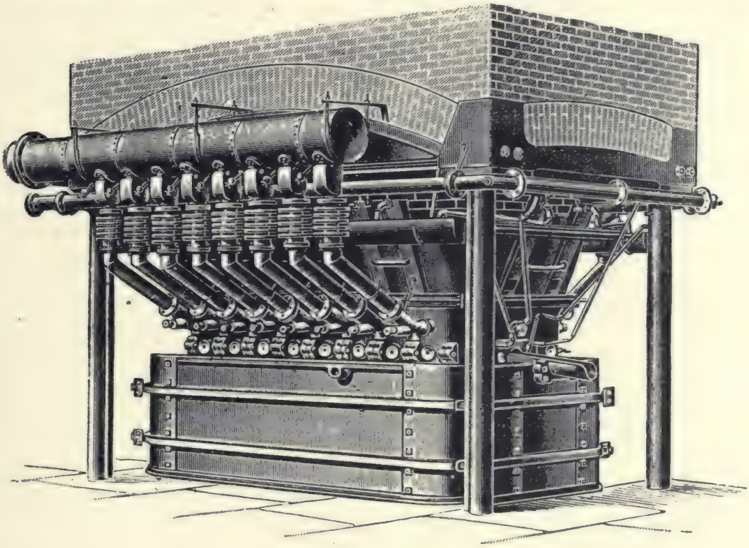


Fig. 12.

REFINING.

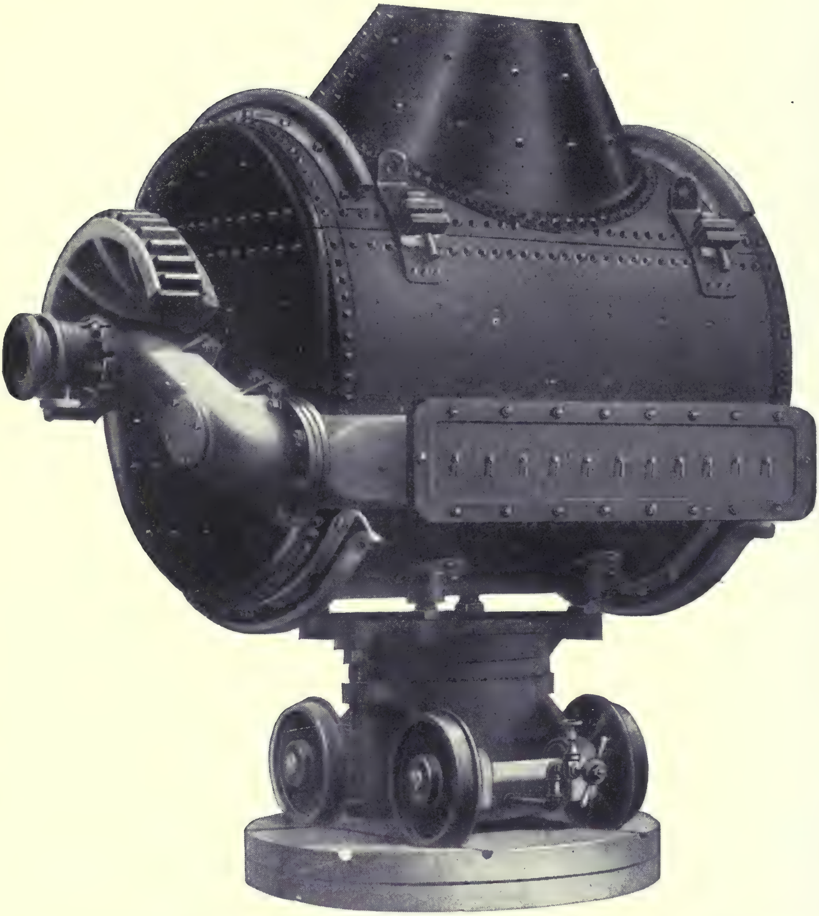
The crude copper produced by any of the foregoing methods is refined in a reverberatory furnace with a large hearth. It is slowly melted down with an excess of air. The impurities oxidize first and form a slag with the silica from the lining of the furnace. This slag is frequently skimmed off. The copper finally begins to oxidize, forming Cu_2O, which acts on any Cu_2S, forming SO_2, which causes the molten metal to boil. When this action ceases, the copper contains too much copper oxide. This is reduced by "poling." Poles of green wood are thrust into the bath, and the distilled hydrocarbon gases cause the bath to boil, which expels any SO_2 gas remaining. Charcoal is spread over the molten metal, which, with the hydrocarbon gas, removes the oxygen from the Cu_2O, leaving metallic copper. Samples are taken out from time to time, and when the color changes from red to flesh color, and the sample becomes fibrous with silky lustre and can be bent double, the refining is finished. The rich slags go back into the process. A little oxide of copper is left in th metal, as it neutralizes the effect of the small amount of remaining impurities.

The metal is then run into small moulds. An ingot "under poled," containing too much oxide, will show a furrow along its surface. An ingot with the right proportion will have a flat surface, called "tough pitch," and one which is "over poled," containing too little oxide, will show a ridge.

Electric refining is fast replacing this older method. In the United States two-thirds of the product is thus refined. By the electrical method all the gold and silver in the copper is recovered, and the copper produced is very pure. The crude copper is cast into slabs as it runs from the furnace. A row of slabs is placed in a tank containing a solution of copper sulphate made acid with sulphuric acid. These form the dissolving plates, and opposite each is placed a thin sheet of pure copper. The tanks are connected in series by wires and the current passed through. The electric current causes the crude copper to dissolve and pure copper to be deposited on the thin plates. The gold and silver, together with other impurities, fall to the bottom as mud or "slimes," from which the precious metals are extracted by chemical processes.

The *wet process* is used for lean ores. It has the advantage of extracting at the same time any gold and silver present. This process involves getting the copper and precious metals into solution either as sulphate or chloride and then the copper is precipitated by electrolysis, metallic iron or quicklime.

The solutions are produced either by dissolving in the dilute



HYDRAULIC TRANSFER CAR AND TURN-TABLE FOR BISBEE CONVERTER
Allis-Chalmers Co.

acids or roasting the sulphide to sulphate or by roasting with salt to obtain the chloride and then leaching with water.

PROPERTIES OF COPPER.

Copper is a rather soft metal and is very ductile and malleable. It can be worked both hot and cold, but should not be heated too hot, as it crystallizes and takes up oxygen. When worked cold it is stronger and harder, but less ductile. Heating and quenching make it softer. Rolled sheet copper has a tensile strength of from 24,000 to 28,000 pounds per square inch, and annealed wire over 40,000 pounds per square inch. Good castings cannot be made from pure copper because they contain blowholes and the shrinkage is too great.

Copper is not affected by the weather, but in damp places it is slowly corroded; carbonate of copper, called verdigris, being formed by the carbonic acid of the air.

The thermal conductivity of copper is high.

The electrical conductivity of good copper is but little less than that of silver, and is about six times that of iron. A very small amount of impurity reduces its electrical conductivity as much as 10 per cent. Antimony is the most harmful impurity from a mechanical standpoint, and should not be over .02 per cent.

The growth of electrical industries has greatly increased the demand and price of copper of late years. It is estimated that 60 per cent of the world's production of copper is consumed in electrical work. The United States produces over 55 per cent of the world's output of copper, or over a quarter of a million long tons annually.

LEAD.

The most important ore of lead is Galena. lead sulphide (PbS). In the United States it is found in the upper valleys of the Mississippi and Missouri Rivers and in the Rocky Mountains. The mines of Spain, Germany and England furnish the bulk of the European product. It occurs in bright, shining, cubic crystals of metallic lustre. When pure it contains 86.6 per cent of lead. Galena usually contains silver, and frequently a small amount of gold. It is associated with sulphides of zinc, antimony, copper and iron. As it is a very heavy mineral it is easily concentrated.

Cerussite — lead carbonate, $PbCO_3$,— is an ore of some importance and is mined in Leadville, Colorado.

SMELTING.

Lead ore is smelted either in reverberatory furnaces or blast furnaces. When using the reverberatory furnace with sulphide ore, the chemical action whereby lead is produced is much the same as in the final stage of copper smelting in the "Welch" method. The ore is partially oxidized to lead oxide, PbO, at a low heat, some sulphate, $PbSO_4$, also being formed. Then the temperature is raised and the lead is produced according to the following reactions:

(1) $PbS + 2PbO = 3Pb + SO_2$

(2) $PbS + PbSO_4 = 2Pb + 2SO_2$

The lead as it is formed runs into a pot, and the operation is repeated until no more lead can be extracted, when it is tapped and the slag withdrawn in a pasty condition. This "gray slag" is usually smelted in a blast furnace for the lead it still contains. This method is simple and the apparatus inexpensive, but its use is limited to high-grade ores containing 60 per cent to 70 per cent of lead, and only 4 or 5 per cent silica. The process requires much fuel and skilled labor.

SMELTING IN A CUPOLA OR BLAST FURNACE.

This process is used for all ores containing over 4 per cent silica, for carbonate ores, and for various lead slags and drosses obtained in purifying the crude lead.

The Furnace is built of brick and lined with fire brick. It is usually oblong in section. The shaft is from 14 to 20 feet high and tapers downward to the boshes, which taper more sharply to the crucible. The section at the crucible is usually about 12 feet by 3 feet 6 inches. The tuyeres, 6 or 8 in number, are placed on each side, near the top of the crucible. The boshes and part of the crucible are cooled by cast or wrought iron water jackets. The furnace is charged through a door in the side, near the top.

As lead is somewhat volatile, provision must always be made for collecting the lead fumes. Various devices have been tried, but long flues, wherein the fumes condense and settle, are most commonly used. The top of the furnace is connected with one of these flues.

The sulphide ores are roasted in a reverberatory furnace or in hand or mechanical kilns. The roasted ore is charged into the blast furnace with suitable fluxes and various mixtures of coke, charcoal and coal as fuel. Iron plays an important part in the smelting, as it is capable of decomposing silicate of lead and is added as an iron slag or as ore if not present in correct amount.

In smelting there is usually a small amount of matte formed, consisting of sulphides of iron, copper, nickel and lead. This is tapped with the slag into a slag pot, where it rises to the top and is separated when the mass cools. The matte is broken up and roasted and its lead and copper recovered. The lead collects in the crucible and is tapped out at intervals.

SOFTENING AND DESILVERIZING.

The lead obtained by either the reverberatory or blast furnace method contains copper, arsenic, antimony and other metals in addition to silver. The impure lead is slowly melted down in a reverberatory furnace. The lead, having a lower melting point than the impurities, liquefies first, leaving a residue containing the copper and part of the arsenic and antimony. The lead is next heated very hot with an excess of air, and then most of the remaining impurities oxidize and form a scum, which is skimmed off. The silver remains with the softened lead and is extracted by the Park's Process. This process depends upon the fact that a small percentage of zinc added to the molten lead will collect all the gold and silver to form an alloy, which, being of less specific gravity, rises to the top, and having a higher melting point solidifies before the lead.

From the softening furnace the molten lead is run directly into a large kettle. Here from 1 to 3 per cent of zinc is added to three successive portions. After each addition the mass is well stirred and then allowed to cool somewhat, when a crust is formed, which is removed. The first crust contains most of the gold and is called the gold crust. The second crust is called the silver crust, and the third crust, containing the silver that still remains, is used for the first addition to the next charge.

RECOVERY OF THE SILVER AND GOLD.

The gold and silver crusts are melted slowly in a kettle or reverberatory furnace, and most of the lead mixed with the crust melts out and is recovered. The zinc is distilled off in large graphite retorts, leaving a small amount of lead, which contains all of the silver and gold. The lead is separated from the precious metals by cupelling. In the cupelling furnace the lead is oxidized to litharge (PbO), leaving the metallic silver and gold. The furnace has a hearth made of porous material, which absorbs part of the melted litharge as it forms; the remainder runs into a pot. The litharge is ground and sold if it does not contain too much silver, in which case it is smelted again. About 60 per cent of zinc is recovered in metallic form and is used again in the desilverizing kettle.

REFINING THE DESILVERIZED LEAD.

The desilverized lead contains .6 per cent to .7 per cent of zinc, which is removed in a reverberatory furnace or large kettle. The charge is heated very hot in the reverberatory, and the zinc in part volatilizes; then the doors are opened and the remainder of the zinc is oxidized, and with some lead oxide is skimmed off. This is repeated until the zinc is entirely removed.

When refined in a kettle, steam is forced into the molten charge; the zinc and a little lead oxidize and form a scum, which is skimmed off.

The desilverized and refined lead is run into iron molds on wheels, and when cooled is ready for the market. The amount of marketable lead obtained is about 80 per cent of the impure lead By using the Howard "stirrer," "skimmer" and "press" for the gold and silver crusts, 85 per cent has been obtained and 70 per cent of the zinc recovered.

An older process for desilverizing lead is the Paterson Process. It is found that when molten lead is cooled slowly, crystals of lead form which contain less silver and other impurities than the remaining molten mass. By repeated crystallization the silver is concentrated in a portion of the lead, and the remainder is almost free from silver. The silver-bearing portion, which must be cupelled, is about 30 per cent of the whole against 5 per cent in the Park's Process. The Paterson Process is not used in the United States.

The working up and recovery of all the by-products formed in the smelting of lead is a very important and very complex part of the process.

PROPERTIES OF LEAD.

Lead is the softest and heaviest common metal. It is very malleable and ductile, but has little tenacity. Lead is insoluble in sulphuric acid of moderate strength and is not much affected by cold hydrochloric acid. It is used in chemical works in the manufacture of sulphuric acid and for other purposes. Ordinary water has little effect on lead. Pipes used for conveying water are soon covered with a thin layer of carbonate and sulphate of lead, which is insoluble and prevents further action.

Water from swamps, etc., however, dissolves small amounts of lead, which makes its use dangerous for domestic purposes. Water from new pipes or pipes which are not kept constantly full should not be used for household purposes, because of danger from poisoning.

Lead is not affected by dry air, but is slowly corroded in moist air.

TIN.

This metal was known to the ancients, and very successfully used by them for hardening copper. The most important ore is tin-stone, $Sn\,O_2$, and the principal mines are in Cornwall, England, and Banca in the East Indies.

The smelting is conducted in a reverberatory furnace. The concentrated ore, mixed with finely divided anthracite coal and with a little lime is heated on the bed of the furnace. The tin is produced and runs into the depressed center of the furnace, from which it is tapped and cast into pigs. This impure tin is refined by liquating and poling.

PROPERTIES AND USES.

Tin is white in color with a slightly yellowish shade. It has a peculiar odor, and when bent it gives out a crackling sound known as the "tin cry." It has little tenacity, considerable ductility, and is very malleable. It can be worked at about the boiling point of water, but becomes very brittle at 400° F. It can be rolled into very thin sheets; tinfoil being sometimes only one-thousandth of an inch thick. On account of its ductility it is readily made into tubes, wire, etc.

The bulk of this metal is used for tin plate. Thin sheets of mild steel are carefully cleaned and annealed and then dipped in a bath of molten tin covered with a layer of tallow. They are then passed through rolls to remove the superfluous tin, leaving a very thin coating of pure tin on both sides of each sheet. Tin plate finds numerous uses in the canning industries, for household utensils, etc.

Almost all of the remaining product is used for making alloys of tin, and only a comparatively small amount is used for pipes, sheets, etc., on account of the high price of this metal.

ZINC.

A large proportion of this metal is obtained from the ore called Zinc Blend, ZnS; the carbonate and silicate are also important ores, and considerable zinc is obtained from Franklinite.

In the metallurgy of zinc advantage is taken of the volatility of this metal. It can be distilled unchanged at 1040° F. The ore is roasted to oxide of zinc, ground and mixed with finely divided fuel and heated to a bright red in gas heated retorts. The carbon takes the oxygen from the zinc oxide, forming CO gas, and the zinc is set free and distills off. It is condensed in iron tubes which are kept at such a temperature that the zinc remains liquid and runs into a receiving vessel.

This zinc contains iron and other impurities, and is purified by redistillation. It comes on the market cast in slabs, and in this form is called "spelter."

PROPERTIES AND USES.

Zinc is a bluish white metal, brittle and crystalline. It is quite ductile at a temperature of 248° F., but is so brittle at 390° F. that it can be crushed to powder.

Zinc is readily dissolved by acids and alkalies, but is not affected by the weather. It is very largely used for galvanizing iron, which is done by dipping the carefully cleaned iron in a bath of molten zinc, using sal-ammoniac as a flux. Zinc protects the iron from oxidation, and is effective as long as any zinc remains on the iron, being the reverse of the action of tin plate which causes the iron to rust more quickly as soon as there is any flaw in the coating. Zinc is also used in making alloys and for batteries, sheets for roofing, etc.

ALUMINUM.

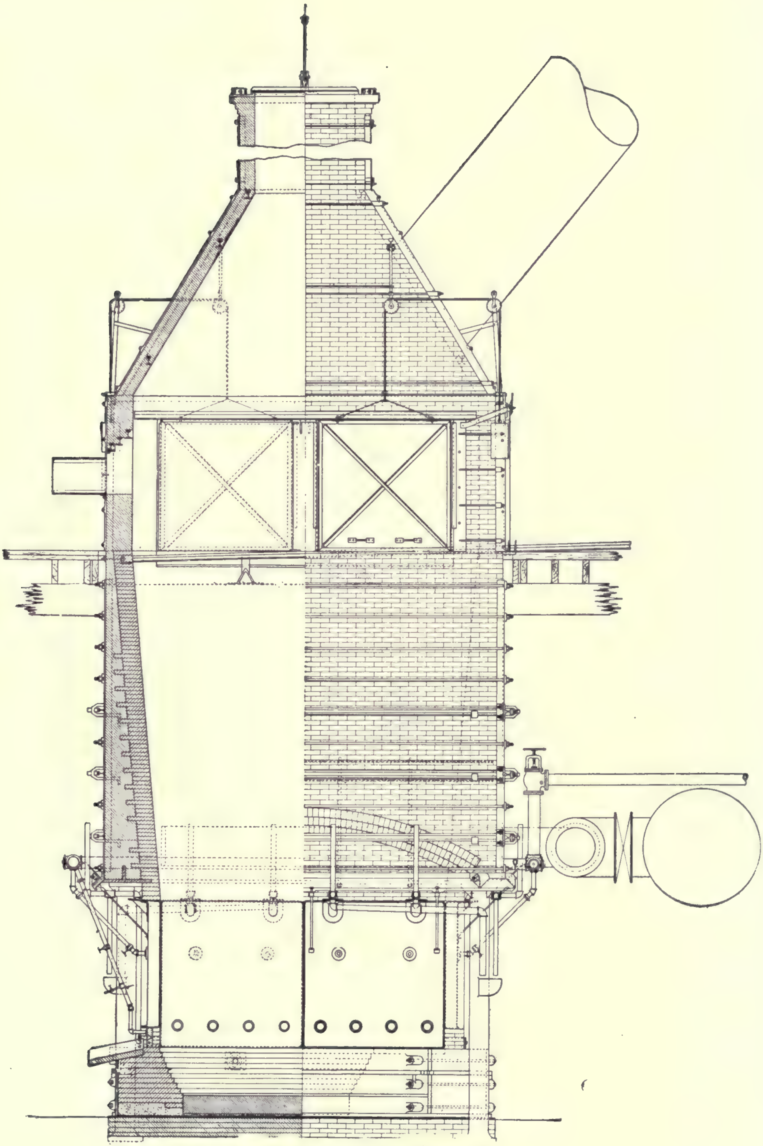
Aluminum has recently been transferred from a rare metal to one which, bulk for bulk is no more expensive than copper, by an electrolytic process invented by Hall. Beauxite, a hydrated oxide of aluminum is the important source of supply. Hall's process is conducted in a graphite lined vessel, and depends upon the property of cryolite — a double fluoride of sodium and aluminum, of dissolving fused oxide of aluminum. Cryolite melts at about 900° F. and then becomes a conductor of electricity. The bath is kept in a molten condition by a heavy current of electricity of low voltage. The oxide of alumina is sprinkled on the top of the bath and quickly dissolves, and is reduced by electrolysis to metallic aluminum which settles in the bottom of the crucible, from whence it is drawn from time to time.

If pure aluminum is desired the oxide of alumina used is obtained by a chemical process from beauxite.

PROPERTIES AND USES.

Aluminum is a grayish white metal, very malleable and ductile, and is a good conductor of both heat and electricity. It is acted on but feebly by sulphuric or nitric acid or by the organic acids. It is, however, dissolved by hydrochloric acid and the alkalies. Its most remarkable property is its extreme lightness, it being only about one-third as heavy as iron. It is fairly strong and imparts great tensile strength to its alloys. Good castings can be made from it, although the shrinkage on cooling is considerable. It can be worked cold, and is readily formed into sheets, wires, tubes, etc.

It is replacing copper to some extent as an electrical conductor, and is used for making a high class of kitchen utensils and a great variety of small ornamental articles. One objection to its use for some purposes is that it can be soldered only with difficulty.



SILVER-LEAD FURNACE.
Allis-Chalmers Co.

TABLE OF METALS.

Name.	Specific Gravity.	Melting Point. Fahrenheit.	Electrical Conductivity. Silver = 100.	Heat Conductivity. Silver = 100.	Tensile Strength. lbs. per sq. in.	Weight per cu. in. in lbs.	Weight per cu. ft. in lbs.	Approximate Price per pound in Pigs, Billets, etc., 1902.
Cast iron	7.0 to 7.7	2100°	12.0	11.4	13,000 to 30,000	.260	445	¾¢
Wro't Iron	7.4 to 7.8	3000°	16.0	11.9	40,000 to 60,000	.278	485	1¾¢
Steel 0.1% C.	7.6 to 7.8	2500°	12.0	11.6	50,000 to 65,000	.283	490	1½¢
" 0.2% "					60,000 to 80,000			
" 0.4% "					70,000 to 100,000			
" 0.6% "					90,000 to 120,000			
Copper	8.8 to 8.9	1930°	99.9	73.6	25,000 to 50,000	.320	555	14¢
Lead	11.2 to 11.4	620°	8.3	8.5	1,600 to 2,400	.410	709	4½¢
Tin	6.9 to 7.3	446°	15.0	14.5	3,000 to 5,000	.263	455	25¢
Zinc	6.8 to 7.2	774°	29.0	19.0	5,000 to 20,000	.258	446	4¾¢
Aluminum	2.56	1100°	63.0	38.0	12,000 to 23,000	.093	160	30¢
Bronze	8.7	1550°	6.5		29,000 to 60,000	.313	541	20¢
Brass	8.4		22.0	23.6	30,000 to 40,000	.300	519	13¢

ALLOYS.

Mixed metals give us alloys, many of which possess useful and valuable qualities not found in the pure metals. The ancients were skilled in making bronze and brass, and many of their products cannot be surpassed at the present day.

In general the alloys of copper with tin are known as bronze, and with zinc as brass, but zinc is frequently added to bronze to cheapen it or change the color, and tin is often added to brass to harden it, so that the line between them cannot be sharply drawn.

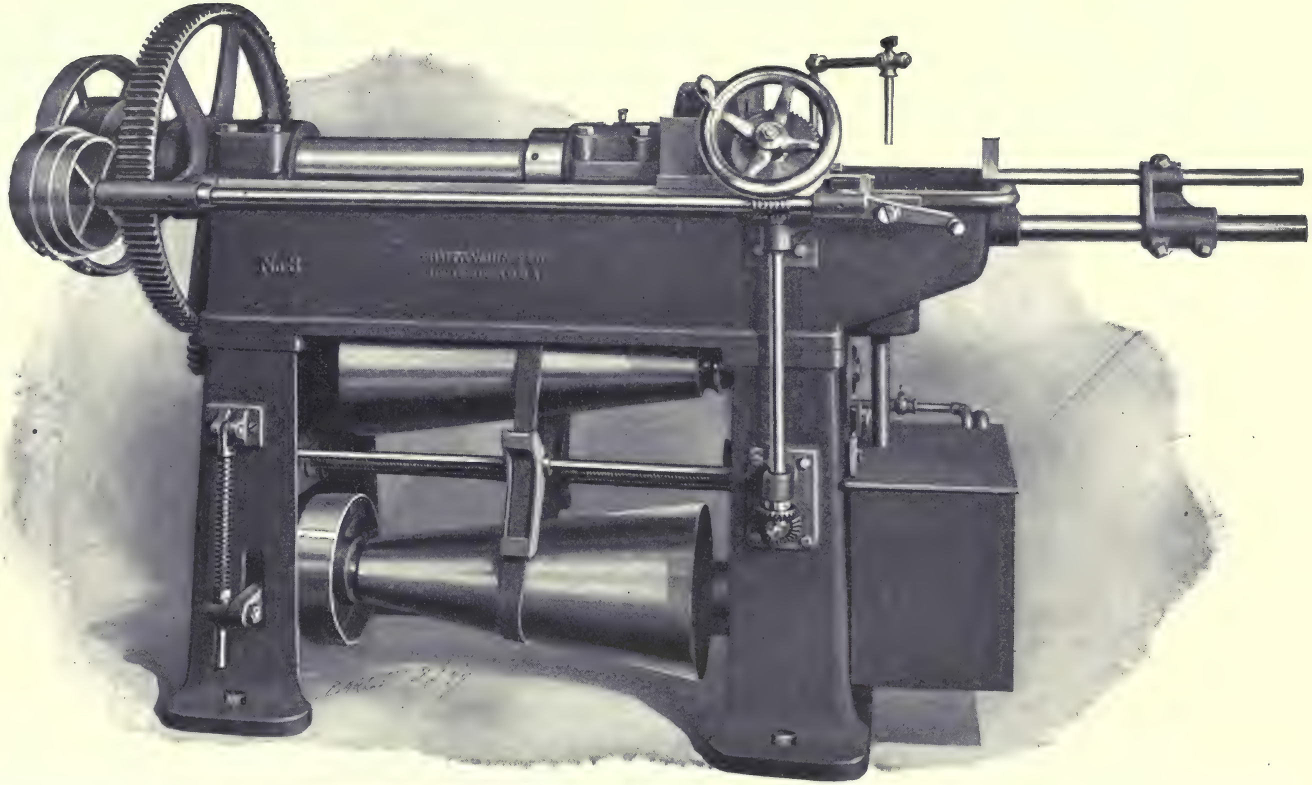
There are countless combinations of metals, but only a few are of general importance. The table given includes most of these with their approximate composition, although each foundry has its own special mixtures. In making alloys, the most infusible metal is melted first, and the others are dropped into the crucible in small lumps, the most volatile being added last. A layer of charcoal is frequently thrown on the surface of the metal to prevent oxidation. In many alloys the metals begin to separate on standing, in which case it is necessary to mix well and pour at as a low temperature as possible, so that the casting will solidify quickly. This is helped by casting in iron moulds. Some metals can not be alloyed in all proportions; thus copper will take up only a small proportion of lead.

To produce finest quality alloys only pure metals can be used, as small amounts of impurities have a very decided effect, just as in the case of iron and copper. The method of making is also important in determining the quality of an alloy. In general alloys which are to be worked into sheets, tubes and wires must be more pure than those required for castings. A small proportion of lead is said to help the rolling qualities of brass, and a very small percentage of phosphorus in bronze makes it more fluid and free from blow holes. The alloys of metals with mercury are called amalgams. One method of extracting metallic gold from its ores is amalgamation, and the effect of amalgamating the zinc in batteries is well known. Formerly alloys were thought to be chemical combinations of metals, but now it is generally considered that they are simply mixtures of metals, sometimes being solidified solutions in each other.

TABLE OF ALLOYS.

Approximate Percentage Composition by Weight.

NAME.	Copper.	Tin.	Zinc.	Lead	Other Metals.	USES AND REMARKS.
Gun metal	91	9				Ordnance, bearings, castings
Bell metal	75	25				Bells, gongs; rather brittle
Bronze coin	95	4	1			Coins, medals
Phosphor bronze	92½	7			½ Phosphorus	Strong castings, heavy bearings
Manganese bronze	89	10			1 Manganese	Propeller blades, pumps. It is non-corrosive and very strong
Aluminum bronze	90				10 Aluminum	Very high tensile strength
Valve metal (best)	88	12	2			Sometimes called "composition"
Valve metal	83	2	15			Cheaper valves, cocks, etc.
Bearing metal	77	8		15	Trace of Phosphorus	Heavy bearings, used on railroads
Brass (common)	66⅔		33⅓			Sheets, wire, tubes, pipe fittings
Muntz metal	60		40			Bolts, nuts; malleable at red heat
Delta metal	56		42		2 Iron	Strong sheets, etc: "Tobin bronze" is a delta metal with a little tin and lead added.
Brazing metal (soft)	50	12½	37½			Low melting point
Brazing metal (medium)	50		50			For copper work
Brazing metal (hard)	75		25			Strongest
German silver	60		20		20 Nickel	Ornaments, resistance wire; composition variable
Fusible plug		10		86	4 Bismuth	For steam boilers
Common solder		50		50		
Fine solder		66⅔		33⅓		
Babbitt's metal	3	89			8 Antimony	The original Babbitt; for bearings
Babbitt's metal				80	20 Antimony	Commonly called Babbitt; used for repair work on bearings
Pewter		80		18	2 Antimony	Plates, mugs, etc.; composition variable
Britannia metal		90			10 Antimony	Table wear, ornaments; composition variable
Type metal				80	20 Antimony	Type and lithograph
Regulus metal				88	12 Antimony	Acid cocks, valves, etc. Sometimes called white metal



CUTTING-OFF MACHINE WITH INCREASED SPEED MECHANISM.

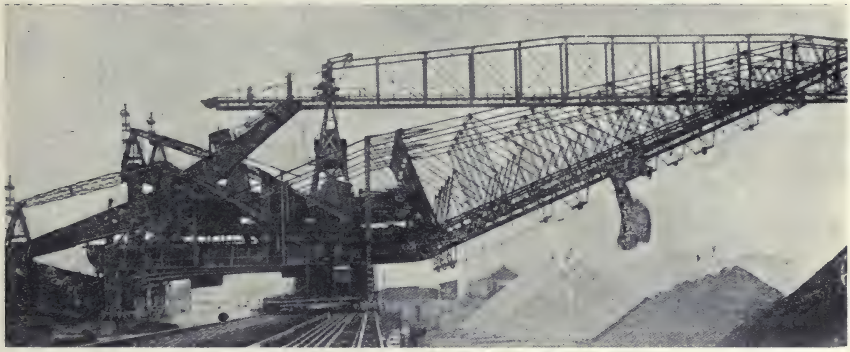
Pratt and Whitney Co.

THE MANUFACTURE OF IRON

Out of the world's annual production of forty to fifty million tons of pig iron, the United States alone furnishes about eighteen million tons, or two-fifths of the entire output. Although the great bulk of this vast production is consumed in the United States, three to four hundred thousand tons are annually exported.

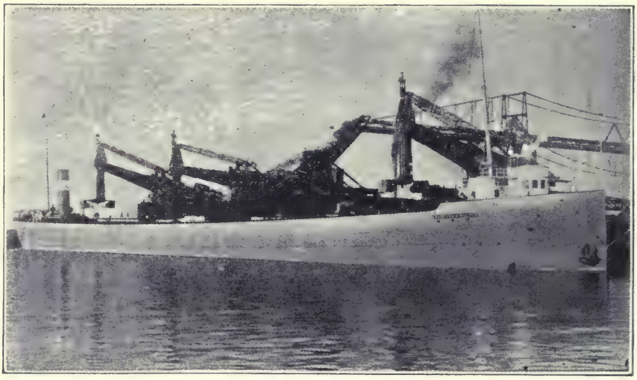
Over forty million dollars are annually paid in wages to the eighty thousand men and boys employed in the production of pig or cast iron. The yearly valuation of this product is over two hundred and fifty million dollars.

The ever-increasing consumptive power of the United States for iron and steel products has caused a phenomenal growth in this branch during the last twenty-five years. During this period it has risen from a little over one million to eighteen million tons. Of this tonnage Pennsylvania contributes about forty-seven per cent, while Ohio produces seventeen per cent, and Illinois about ten per cent. The growth of iron manufacture in these three states has been one of the most notable features in the industrial growth of the United States. The production of Pennsylvania alone to-day is seven times greater than the entire production of this country in 1870.


The Unloaders and Stock Pile of a Modern Dock.

In 1870, when railroad construction was most active in this country, England, which produced three times as much iron as did this country, furnished us with all of our rails and other material, After that, Germany took the lead, but only to be surpassed by the United States, which to-day has an output almost equal to that of England, Germany and France combined.

The great and rapid advancement of the United States in this branch of industry is due, to a great extent, to its rich, reliable and easily obtained iron ore and its unsurpassed coking coal, the two forming the most essential ingredients used in iron making. These, aided by the modern and inexpensive handling and by splendid transportation facilities, reduce the cost of manufacture to such a low figure that American iron can be transported and sold in foreign countries at a large profit.



Unloading a Vessel.
The modern method of unloading the huge ore-carriers at the rate of six to seven thousand tons every ten hours.

The channels of consumption of this enormous tonnage are numerous and extensive, affecting almost every walk of life. Five million tons is of grades suitable for foundries, for the production of iron castings for machinery, railroad rolling stock, cast-iron pipes, and a variety of small uses. About half a million tons is converted into wrought iron, while another half million is used for steel castings. The remainder, amounting to about eleven million tons, is utilized as the basis of steel manufacture.

The actual manufacture of iron dates back almost to the prehistoric era, but it was not until 1620 that it was introduced into the United States. From that time on the improvements were rapid and wonderful, the foremost of which were the introduction of coke in the eighteenth century, the steam engine in 1769, and the hot blast of J. B. Neilson in 1828.

A splendid example of one of these antiquated furnaces can still be seen near Lakeville, Conn. It was built in 1762; and so excellent was its product that cannon, cannon balls, shells, etc., were used therefrom, as also the large chains which were stretched across the mouth of the Hudson during that exciting period.

Pig or cast iron is not pure iron, but an alloy of which iron is the most important ingredient. Unlike many of the common alloys, such as bell metal or brass, which are composed of a mechanical mixture, it consists of a large, complex union of many and different elements, such as carbon, manganese, silicon, sulphur, phosphorus, etc. The most important of these is carbon, which gives fluidity to the metal when molten and hardness when cold.

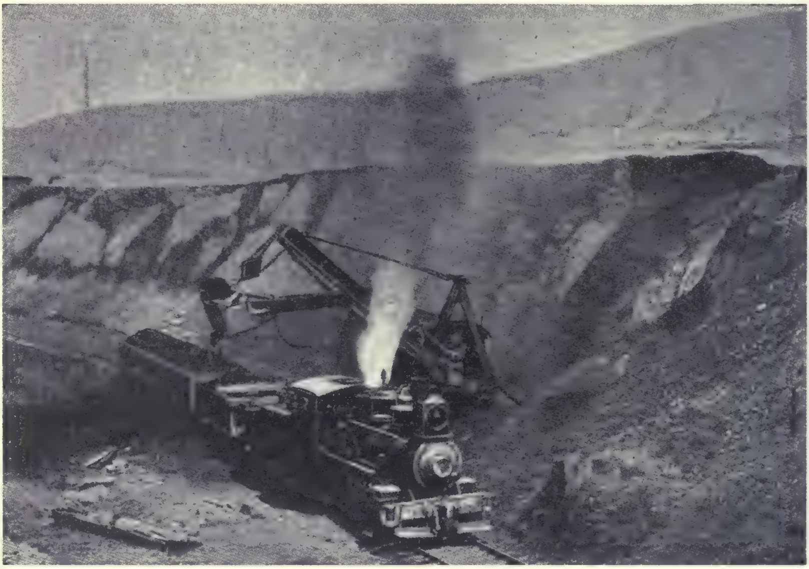
Old Method of Unloading Ore Vessels.

The three principal ingredients used in its manufacture are iron ore, coke and limestone. In a few cases, charcoal, anthracite and bituminous coal are used, alone or mixed, in place of the coke. All of these are plentiful in this country and of most excellent quality.

The iron ores of this country are divided into four general classes, the high-grade ores containing about fifty to sixty per cent of iron, and the low ores, thirty to fifty.

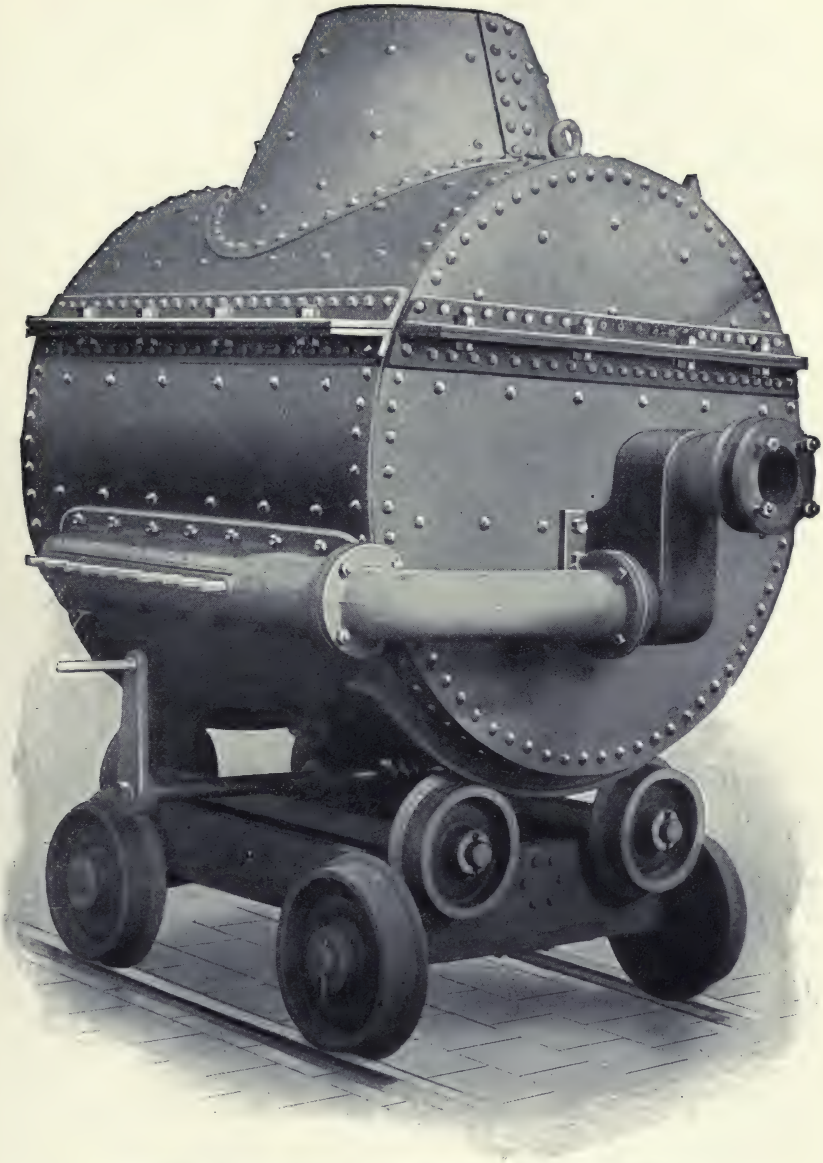
Although small quantities of ore are found in Alabama, New York, Pennsylvania, New Jersey, Wisconsin, Minnesota, Michigan, Virginia, and West Virginia, about eighty per cent of the total is mined in the famous Lake Superior region, of which the following are the principal ranges: The Masaba in Minnesota, the Menominee in Michigan and Wisconsin, the Marquette in Northern Michigan, the Gogebic in Michigan and Wisconsin, and the Vermillion in Minnesota.

The iron ore in the United States may be considered in four general commercial classes—red and brown hematite, magnetite, and carbonate. Of these four, the red hematite is the most popular, because of its richness in iron and its freedom from foreign and non-metallic material. These classes are subdivided under various local or trade names.

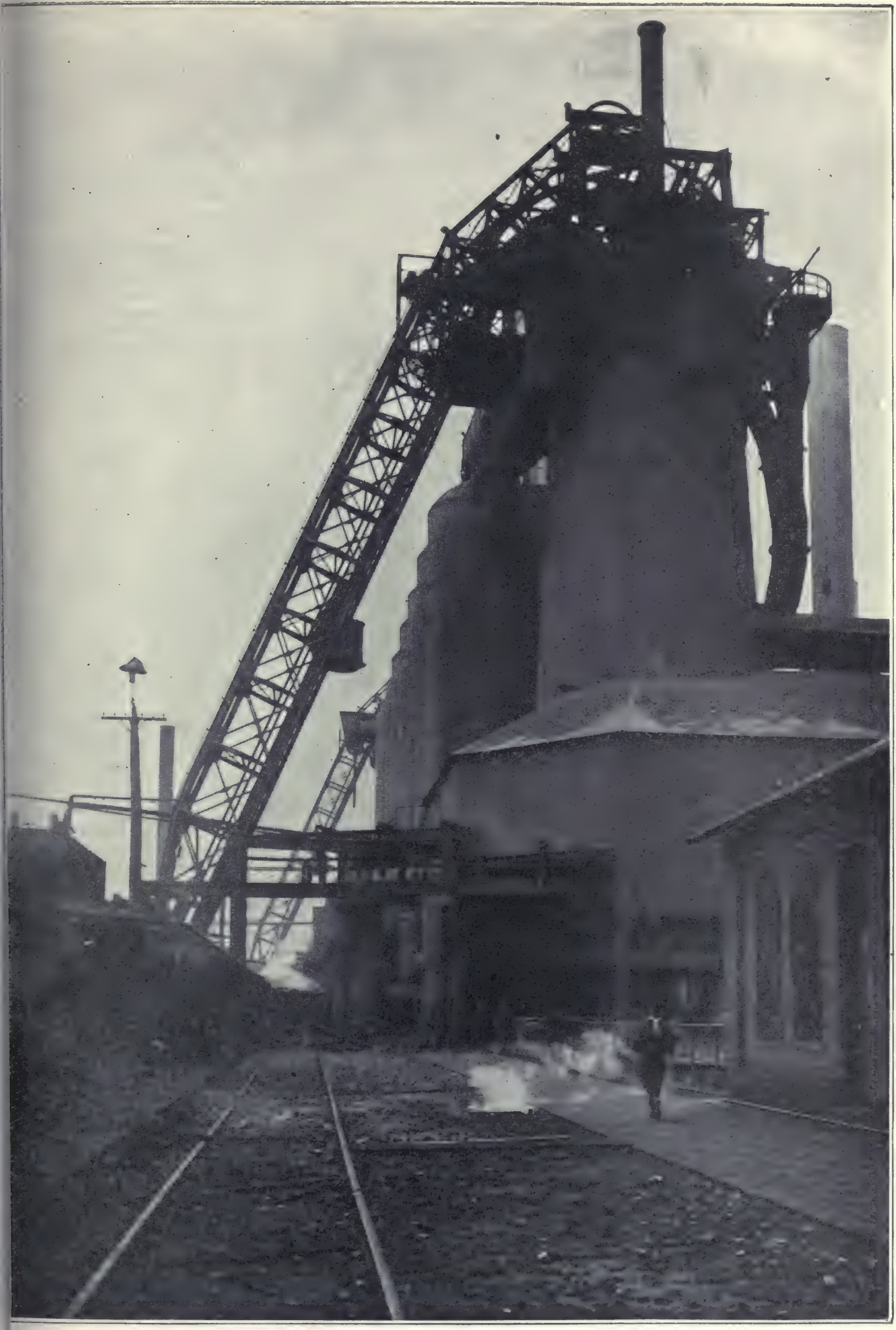


A Steam Shovel "Bucking" a Bank of Ore.

Three general methods are employed in the United States in mining the ore—surface, drift, and underground. In locations where the ore is very hard or lies at a depth of sixty feet or more from the surface, the latter method is employed. Shafts or tun-



SMALL CYLINDRICAL CONVERTER. For Copper Matte.
Allis-Chalmers Co.

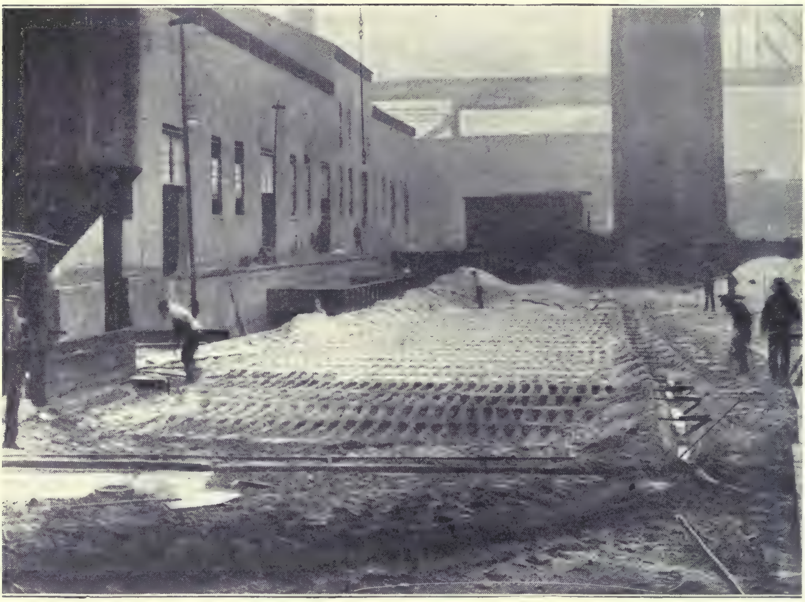


Modern Blast Furnace, the Record-Breaker of the World.

he cut shows the skipway, up which the material is carried to the top of the furnace. The downcomers, or pipes down which the gas travels, are also very plainly illustrated.

nels are driven to the ore beds, which are then worked in a similar manner to coal. In those districts where the ore is found in a loose condition just under the surface, surface mining is almost altogether followed.

Surface Mining. Where surface mining is employed, the ore must be easy to get at. The top soil is first removed by steam shovels, after which the ore can readily be taken out in the same manner. The mine being thus opened or "stripped," tracks are laid in all directions upon the face of the deposit. These excavations are usually worked in terraces. The ore, being lifted by the numerous steam shovels, is placed directly on specially constructed cars, in which it is hauled to the docks. In this manner immense quantities of ore are obtained at a cost not exceeding forty cents a ton, while the drift and underground require an expenditure of seventy to eighty cents a ton.



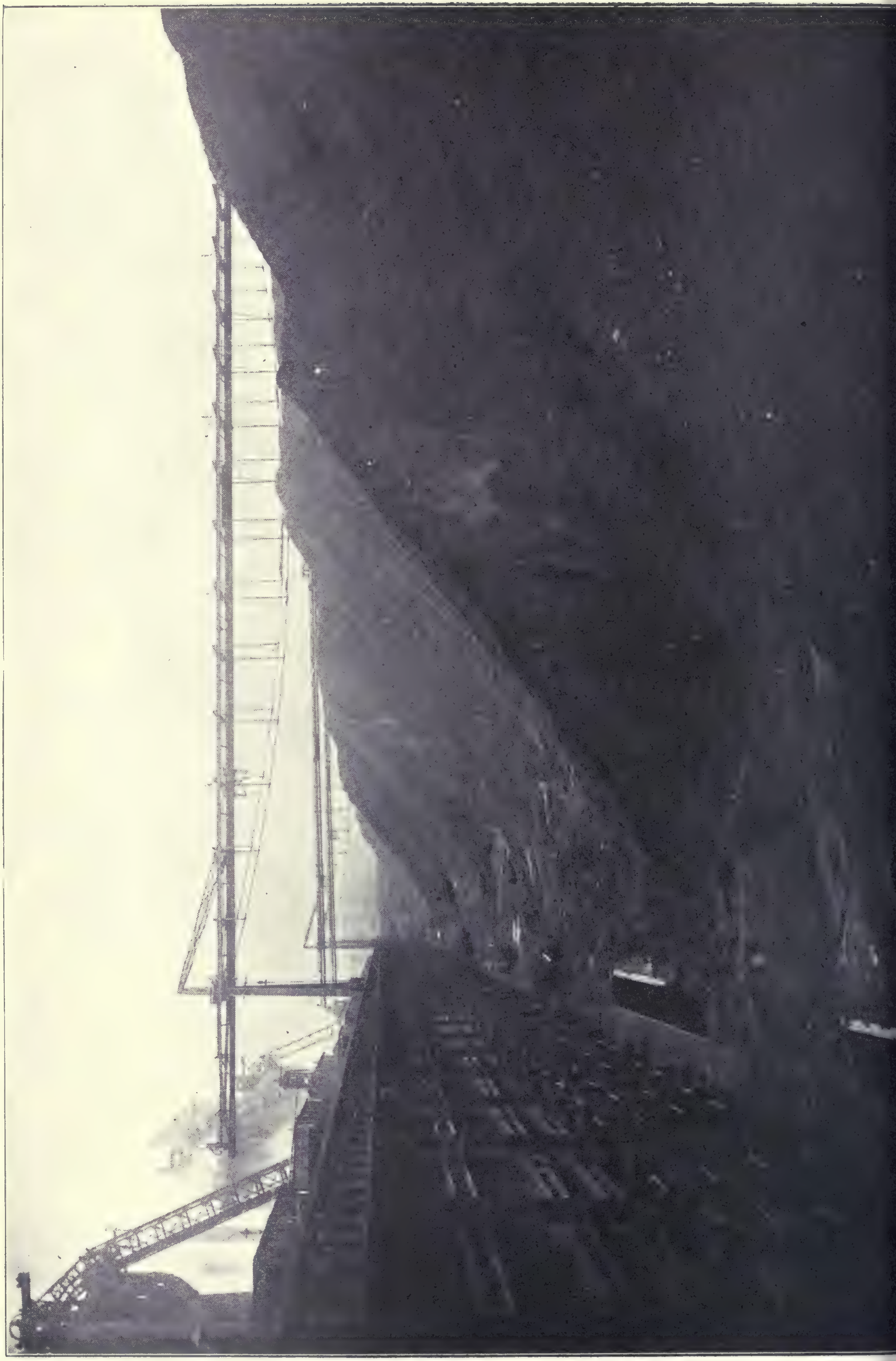
A Stream of Molten Iron Running into the Sand Moulds, Forming the Rough Bars, which, when Solidified, are Termed "Pigs."

The ore ranges of Lake Superior have added more to the economical advancement of American iron than any other single thing. They have given birth to the thousands of miles of railroads that are scattered throughout that district and that devote their entire traffic to the transportation of iron ore. They have added to the Great Lake shipments millions and millions of tons; given employment to thousands of boat builders and crews; forced the Government to make improvements throughout their course; and caused the growth of towns all through the mining districts and the building of the largest docks in the world.

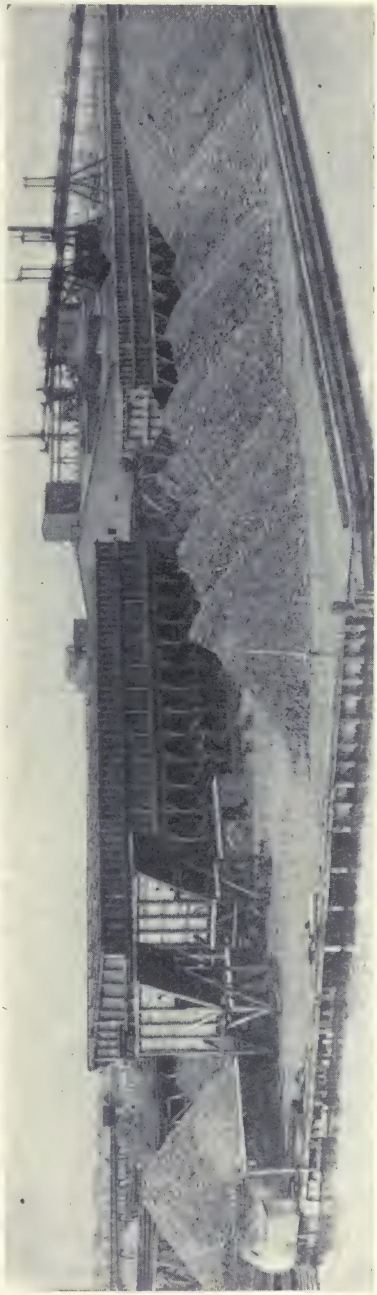
Docks. With typical American enterprise these docks are built with the latest labor-saving devices. The specially constructed cars are run out upon them, and their hopper floors dropped, permitting the ore to fall into numerous bins below. Underneath and on both sides are long rows of chutes through which the ore passes into the holds of the large ore-carriers. These boats are invariably filled to their very hatches. Over twenty-one million tons of ore were transferred through these docks last year. The magnitude of these structures can therefore readily be imagined. In winter all shipments are suspended; consequently a large accumulation of ore must always be stored in the East, either at the docks or at the furnaces. Some vessels have a tonnage of six thousand tons, and so perfect are the loading facilities that it seldom requires over five hours to load them. After a trip through Lakes Superior, Michigan, Huron, and Erie, the immense ore vessels arrive at one of the unloading docks of Cleveland, Conneaut, or Ashtabula.

An Old-Time Blast Furnace.
One of the first furnaces in this country, still standing near L·ikeville, Conn.

Here on every side are the huge yet rapid machines that transfer the ore from the ship's hold to the huge pile on the docks. These machines have grown to such perfection and magnitude that



the ore boats are rarely held longer than ten hours to have their contents transferred to the storage piles.



A Modern Ore Dock.

As wanted, the ore is loaded into cars, either directly from the steamers or from the stock piles, and transferred by rail to the furnaces. The great Pittsburg district is the destination of the greater portion of this ore. So thoroughly mechanical and free from labor have been these numerous operations of mining, loading, transporting, and delivering the ore in the Pittsburg district, that an expenditure of only two dollars and fifty cents a ton has been incurred.

The greatest advancement which American iron manufacture has made in recent years is in the handling of the raw and finished materials at the furnaces. This is due largely to the great increase of tonnage during the past ten years. Over ninety million tons of raw and seventeen million tons of finished material were handled in 1905 at the four hundred and twenty-eight furnaces scattered throughout the United States. The raw material alone represents an expenditure of over one hundred and thirty million dollars.

In contrast with the oldfashioned method of hand labor, mighty machines are to-day employed. From the moment the long trains of ore, coke, and limestone arrive, through the period of unloading, charging, melting, casting, and loading the finished iron, man never once enters into the operation. The ore cars are lifted upside down and their contents dumped into large iron buckets, which automatically carry them either to the long row of bins or to the large stock piles. The cars containing the coke and limestone are run upon a trestle under which are arranged the bins. By this method they can deliver their contents directly into the bins without any additional handling, the cars being provided with bottom gates. Many of the largest plants have sufficient bin space to permit a large quantity of ore to be similarly stocked, thus reducing the cost and holding the large stock supply for emergency and winter usage.

THE BLAST FURNACE

The modern blast furnace is a gigantic structure, oval in shape and some ninety to one hundred feet in height. It consists of an outer coating of steel plates, with an inner lining of fire brick. Accompanying these stacks are invariably two or more cylindrical steel structures known as stoves. They are usually smaller in diameter but as high as the stacks themselves. Their particular work consists in utilizing the waste gases to heat the blast for the furnace.

Charging. Running parallel to the long row of furnaces are the immense steel bins or trestles filled with the ore, coke and limestone. At the bottom of this structure are small electric cars which are kept busy, transferring the desired ingredients—ore, coke, and

The Casting Machine.
The modern method of solidifying the iron.

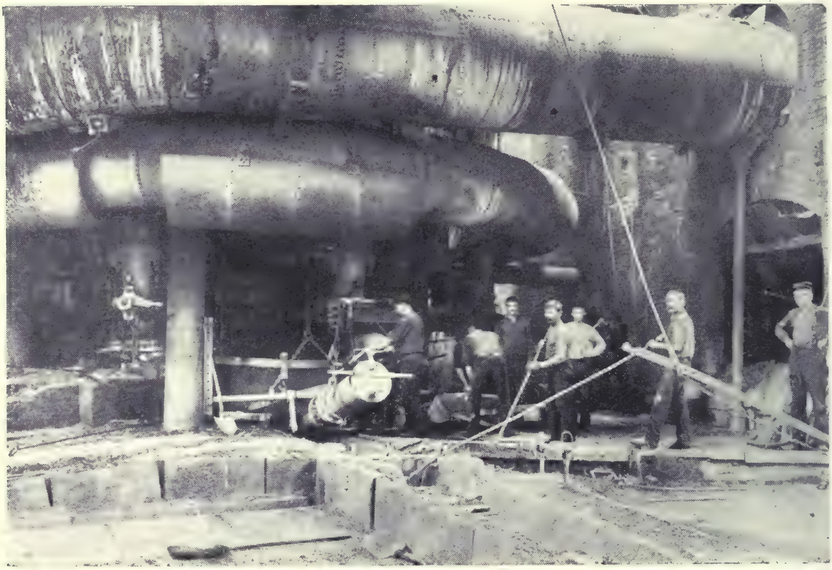
limestone—from the pockets at the bottom of the bins to the skip car. This being done, the skip, which operates upon an inclined track from the ground to the top of the furnace, is conveyed to the top, where it automatically empties its charge into the upper or receiving bell. When filled, the bottom of this bell is lowered and the material allowed to fall into a second and larger receiver. When this has received its full quota, consisting of several such loads and known as a "charge," its bottom is lowered and the charge distributed uniformly in the furnace over the top of the previous charge. By these two bells or bottoms, the top of the furnace is at all times closed. The furnace is usually kept filled within a few feet of its top.

Running the Molten Iron into Ladles.

But this is only a portion of the operation. Encircling the lower outside portion of this tremendous test tube, so to speak, is a large pipe punctured at regular intervals by smaller ones which terminate in the interior of the furnace. The powerful air-blast goes rushing through these pipes into the body of this mass, where every atom of it is caught and utilized in some form or shape for the complicated reaction therein.

There are two distinctive series of operations in the blast furnace—those which accompany the charged materials on their downward journey, and those of the ascending gases.

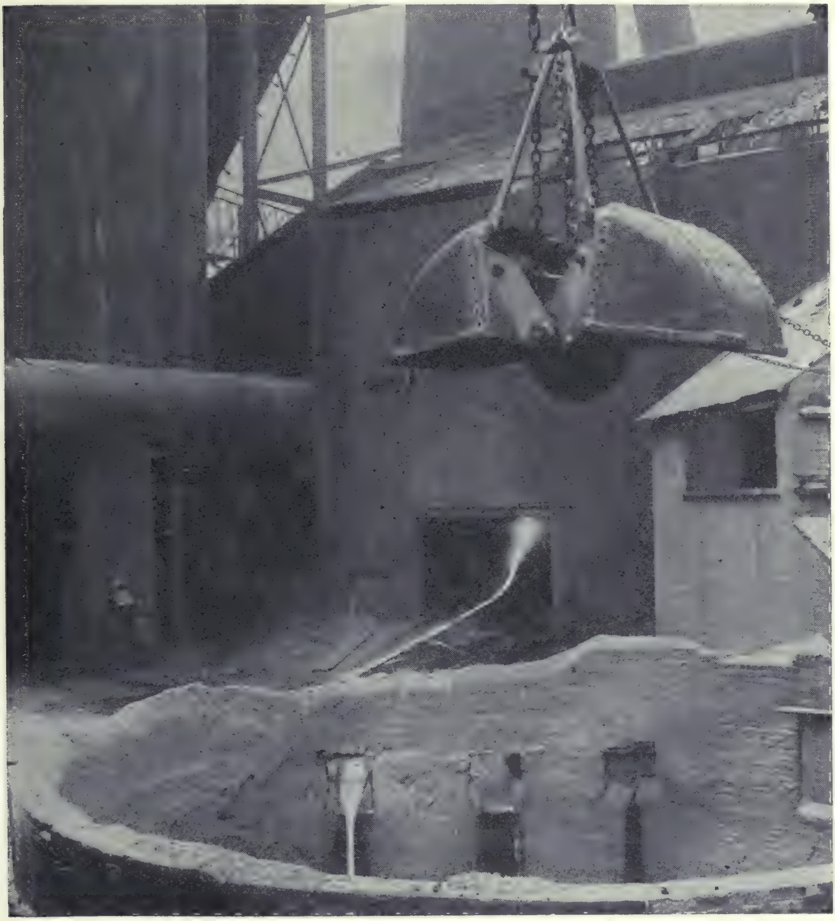
As before stated, the superheated air-blast enters the lower portion of the furnace from all sides at a pressure of about sixteen pounds to the square inch. Immediately upon its contact, the coke or coal, whichever is used as fuel, becomes combustible, the oxygen of the blast uniting with the carbon of the fuel, forming the gas CO_2 and a most intense heat. This gas ascends, and during its contact is reduced to CO. Upon its contact with the highly heated ore and limestone, the CO reduces the ore, the other gases assisting by heating the materials in the upper portion of the furnace. The limestone is first changed into caustic lime, which unites with the alumina and silica of the ore and ash of the fuel, with the result of a double silicate of lime and alumina. This is very fusible and does not mix with the iron.



Closing the Iron Notch after Running a Blast from the Furnace.
The large pipe circling the furnace is the bustle pipe, through which the hot blast is carried to the furnace.

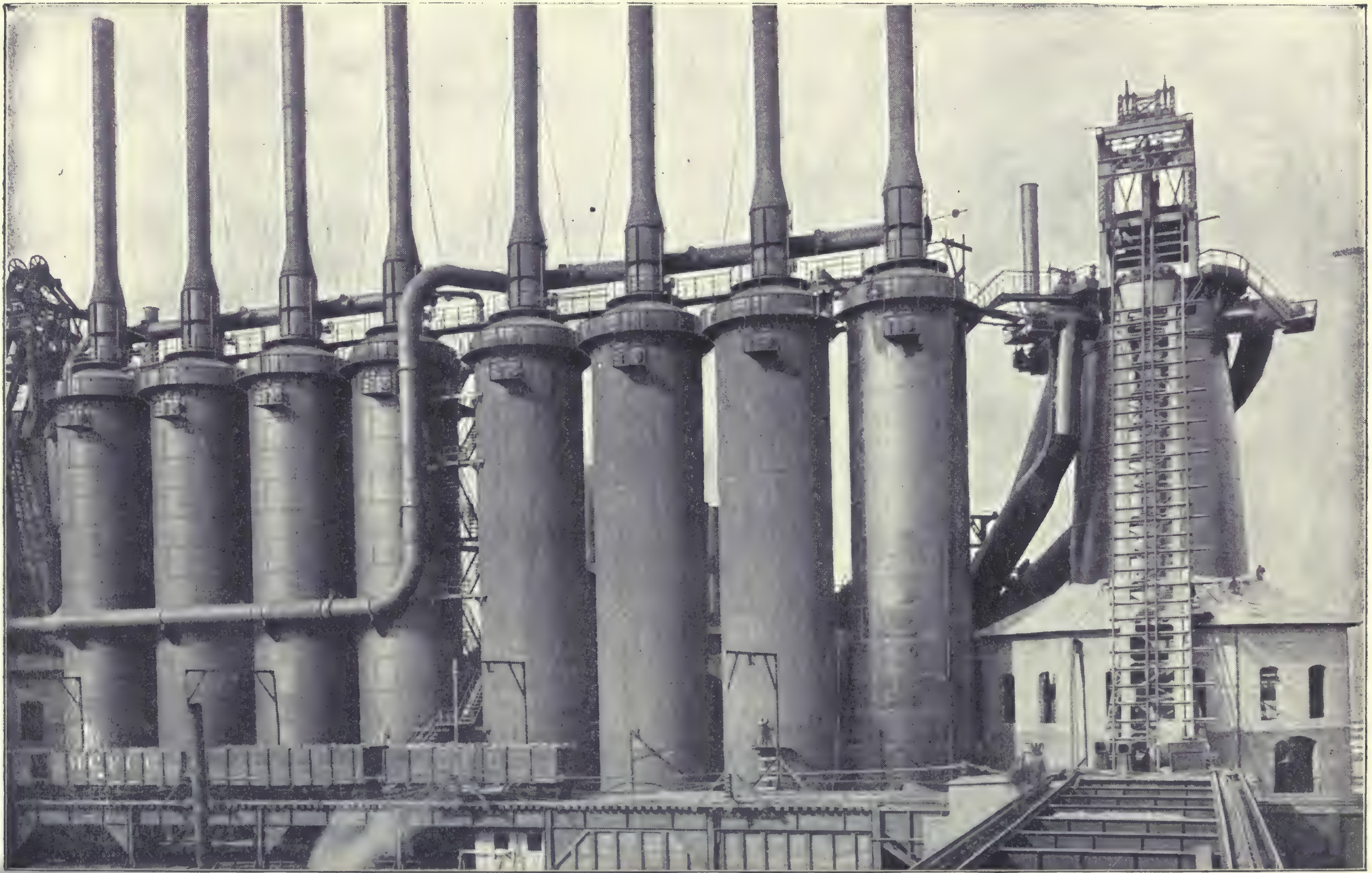
The incombustible and solid matters are so mixed and proportioned with the combustible and fusible materials that the entire charge, when heated, will result in only fusible matter.

The slags, caused from the earthy matters of the ore mixing with the fluxes, follow the iron on its downward course. This, in turn, drips or falls into a large brick-lined receptacle in the bottom of the furnace. Owing to their lower specific gravity, the slags float on top of the iron, protecting the same from the influence of the blast.



Running the Hot Slag from the Furnace into the Cinder or Granulating Pit.

Utilizing the Gases. The gases accumulating from this con-



A Modern Blast Furnace with its Army of Stoves, glomerate mass of liquid, semi-liquid, and heated substance, rise to the top. Not finding an escape through the charging bells, they dart down the two or more "downcomers" which are provided for this purpose. Here they are led through a box, where the cinders and other solid matters are extracted. A portion of the gases is now carried through pipes to feed the boilers, while another portion is utilized in the heating of the stoves.

These stoves, as before mentioned, are large, cylindrical structures whose interiors are masses of fire brick. These bricks are so arranged as to allow the greatest amount of surface to be exposed. In this manner they are thoroughly heated. Each furnace has a set of such stoves, some of which are always being heated, while others are giving their heat to the blast which is driven through them prior to entering the blast furnace proper. At intervals these stoves are changed, the cold ones heated and the hot ones employed for heating. This method of utilizing the waste gases is a comparatively new invention, but one which has almost revolutionized the iron industry.

Casting. Formerly there was but one method of casting pig iron; but, because of the rapid advance in the uses to which this material is adapted, several methods are now employed. The ultimate results of these methods are of a physical rather than a chemical nature. In any case, however, the iron is first tapped through an opening near the bottom of the furnace, at periods of four hours' duration. Leading from this is a long channel in the sand, through which flows the white, glittering iron.

If it is to be cast in the form of sand pig, the metal runs into a long channel in the sand, with smaller ones running at right angles to both sides. These are called "sows." Flowing from the sows, the iron is fed into smaller moulds, about three feet long and four inches wide. When solidified, these "pigs," as they are termed, are broken from the sows and loaded into cars, ready for shipment. Iron thus cast has an accumulation of adhesive sand upon its surface. It is not extensively used in any processes where sand or silica is a detriment.

When wanted for basic purposes and free from sand, another method is employed. Instead of permitting the iron to run into the sand moulds, it is run through the channels into specially constructed ladles or vessels which operate upon wheels. These have a capacity of 18,000 pounds each; five to six are usually filled from each blast or cast. As filled, they are drawn to the casting house, where they are tilted in such manner as to permit the molten metal to run into an endless chain of cups. These cups are about two feet long and eight inches wide at the base, and are attached to an endless chain that rests upon a track. By means of an engine or motor, the chain is revolved, the cups passing through a long tank of water, at the end of which is an incline, up which the chain bearing the cups passes. When it reaches an elevation of about ten feet, the chain passes over two gear wheels on its way back. The cups turn up-side-down, throwing their now solid contents into a car beneath.

Filling the Skip Car with the Necessary Material to Make a Charge.

During recent years the expense of casting has been greatly lessened by the invention or practice of using the iron direct in its molten condition. It is transferred in ladles direct from the blast furnace to the steel furnaces, thus avoiding a second melting in the latter operation.

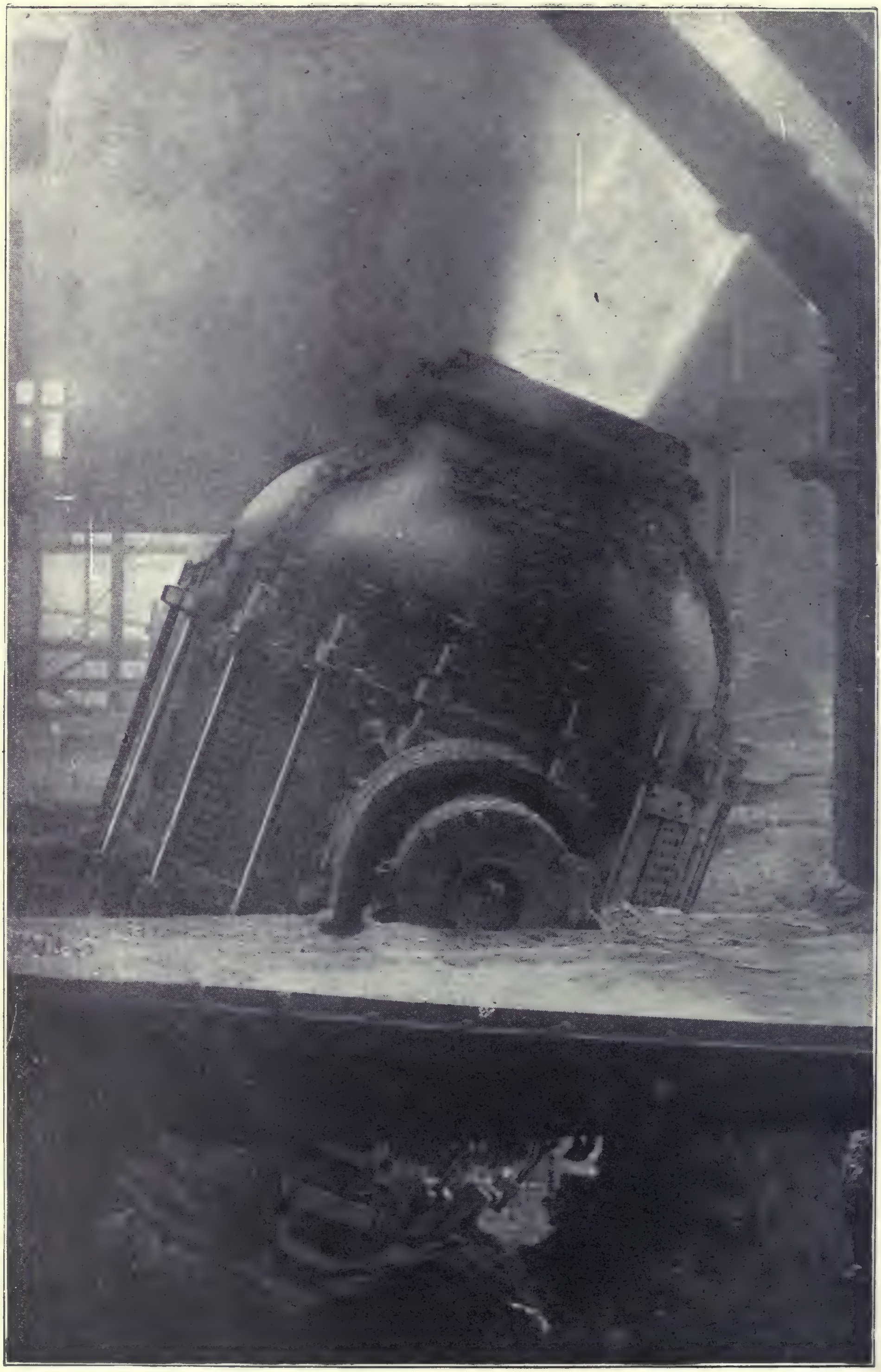
The slag is run off at irregular intervals, in a manner similar to the iron, but through an opening above the iron line. This avoids any possible waste of iron. Channels are built in the sand to lead the slag from the furnaces to either a granulating pit or to the ladles. In the former case it falls into a large pit or well containing water. The hot, liquid slag, coming in contact with the water, solidifies in the form of shot or sand. This is continually being lifted out by large electric scoops and loaded into cars. In this form it is utilized either for cement or ballast. If ladles are used, the molten slag is allowed to flow into several specially built ladles, which, when filled, are carried away and dumped into ravines and hollows.

There are many grades of iron, different only as to their chemical composition. The most common of these are: Foundry, gray forge, mottled, white, standard Bessemer, basic and malleable Bessemer. The foundry irons are subdivided into Nos. 1, 2 and 3, according to the percentage of silicon.

ANALYSIS OF PIG IRONS

The following table gives a rough analysis of the several grades of pig iron:

GRADE	SILICON	SULPHUR	PHOSPHORUS	MANGANESE
No. 1 Foundry	2.50% to 3.00%	.03% and under	.40% to .80%	.30% to .60%
No. 2 Foundry	2.00% to 2.50%	.04% and under	.40% to .80%	.30% to .60%
No. 3 Foundry	1.75% to 2.25%	.05% and under	.40% to .80%	.30% to .60%
Gray Forge	1.25% to 1.75%	.07% and under	.40% to .90%	variable
Mottled	about 1.00%	.10% and under	variable	variable
White	about 1.00%	.15% and under	variable	....
Standard Bessemer	1.00% to 2.00%	.05% and under	.10% to .20%	....
Basic	1.00% and under	.05% and under	.50% to 1.00%	....
Malleable Bessemer	1 25% and under	.05% and under	.05% and under	....



A BESSEMER CONVERTER IN FULL BLAST, TURNING IRON INTO STEEL.

THE MANUFACTURE OF STEEL

This is the age of steel. From the delicate embroidery needle to the one hundred-ton gun, the most important tools of civilization are made of steel. The steel industry is the index to the prosperity of the whole people; it marks also the place of a nation among its peers.

The United States makes more than one-third of the world's production of steel—fifteen millions out of a total of thirty-six and one-half millions of tons; it is the richest and most prosperous among the nations. The two statements are complementary. Germany comes second, with an annual production of 8,000,000 tons; and England third, with 5,000,000 tons. The 450 steel works scattered throughout the United States represent a total investment of over $442,000,000, and pay $103,000,000 annually in wages. These figures cover only the actual production of steel in its crude form, a process in which man has rapidly been superseded by the marvelous and all but human machines. The magnitude of the industry in its entirety, representing a capital of billions and employing millions of wage-earners, may therefore be imagined.

Definition of Steel. Steel is so closely allied, in certain particulars, to cast and wrought iron, that a complete and satisfactory definition of it is almost impossible. Though differing considerably in their physical and chemical properties, they are all alloys of iron and carbon, the essential difference among them being in the percentage of carbon. Wrought iron usually contains less than 0.30 per cent of carbon, and is not materially susceptible to hardening when suddenly cooled. It invariably contains slag and is malleable. It is the product of the "puddling" furnace.

Steel usually contains between 0.08 and 2.00 per cent of carbon. Although its minimum limit extends within the bounds of wrought iron, it is free from slag. With but few exceptions, steel is capable of hardening and is malleable at some temperature.

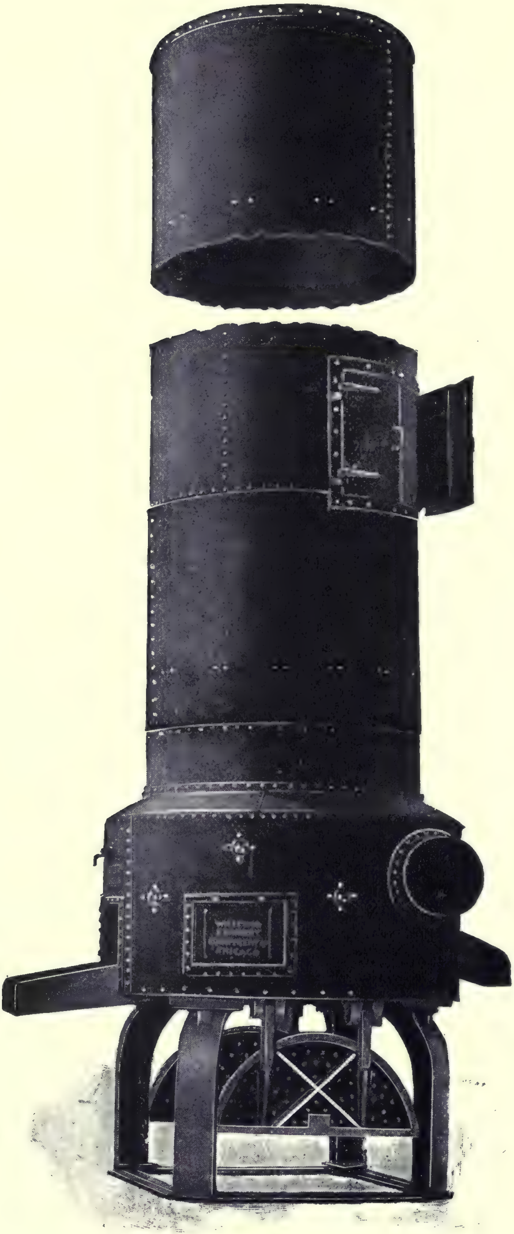
Cast or pig iron contains, as a rule, between 2.00 and 4.00 per cent of carbon, but is not malleable at any temperature. From these definitions, therefore, it is seen that steel is the alloy between cast and wrought iron.

Processes Used. To obtain the physical and chemical properties needed for the numerous and almost totally different uses to which steel is put, several processes are employed in the conversion of the iron scrap and other raw materials into steel. The most important of these are the "Bessemer," the "open hearth" and the "crucible" processes. The first of these, named after the great inventor, Sir Henry Bessemer, is the method by which the majority of cheaper steels are manufactured. Accordingly, we find the great tonnage of rails, structural shapes, shafting, and the lower grades of sheets and wire, produced in this way. The open hearth process furnishes the steel for springs, shovels, the better grades of wire, forgings, plates and other articles, in which a higher grade of material than Bessemer is required, yet a grade not so fine as Crucible. When the highest grade of product is desired—such as edge and cutting tools, surgical instruments, razors, saws, die blocks etc.—steel from the crucible furnace is utilized.

Crucible Process. Crucible steel is made in much smaller quantities than the other forms of steel, the endeavor being to obtain quality rather than quantity. Consequently it is a very high-priced steel, the finer grades selling as high as sixty to eighty cents a pound.

The mixture for melting, consisting of definite and carefully weighed amounts of certain grades of wrought iron, blister bar, alloys and scrap, according to the grade of steel desired, is packed in pots varying in capacity from 50 to 150 pounds. These pots are usually composed of plumbago and German clay, although in England a clay pot is almost altogether used. The life of the plumbago pot varies according to the manner of treatment, the mixture of materials melted within it, and the quality of the pot itself; but on a rough average it might be stated that each can be used three times. The pots being filled, and a cap placed upon each, they are lifted one by one and placed in the furnace.

Although the crucible process is one of the oldest, but little advance has been made in its operation. The furnaces of to-day

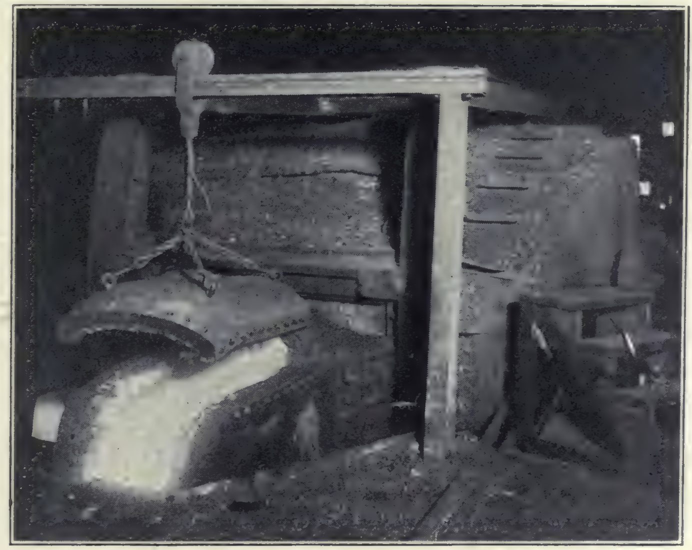


THE WHITING CUPOLA.

and the methods employed, are practically the same as those in vogue during the times of our forefathers in 1789.

The furnace proper consists of numerous holes, varying in number according to the size of the furnace. In America the furnaces usually contain from four to ten holes, six pots being placed in each, three abreast and two deep. The pots rest upon a thick layer of coke dust, which is able to withstand a very severe heat without becoming spongy or liquid, the coke dust making a very firm yet easy rest for the pots. Each hole is provided with three covers, which are easily removed by means of a lever.

The furnace being thus charged, and the covers placed over the holes as closely as possible, the gas and air are permitted to enter. Rushing through the superheated chambers on one side of the row of holes, they meet and pass through the flues into the furnace.



Molten Iron Being Poured from the Mixer into Ladles.
It is in this vessel or furnace that the iron is mixed uniformly, previous to being used in the open hearth steel furnaces.

Circulating around the pots, this heated gas, which rises in temperature to about 3,000° F., finally passes through the opposite flues into the chambers on the opposite side. Passing through

these and thoroughly heating the same, it finally passes up the stack.

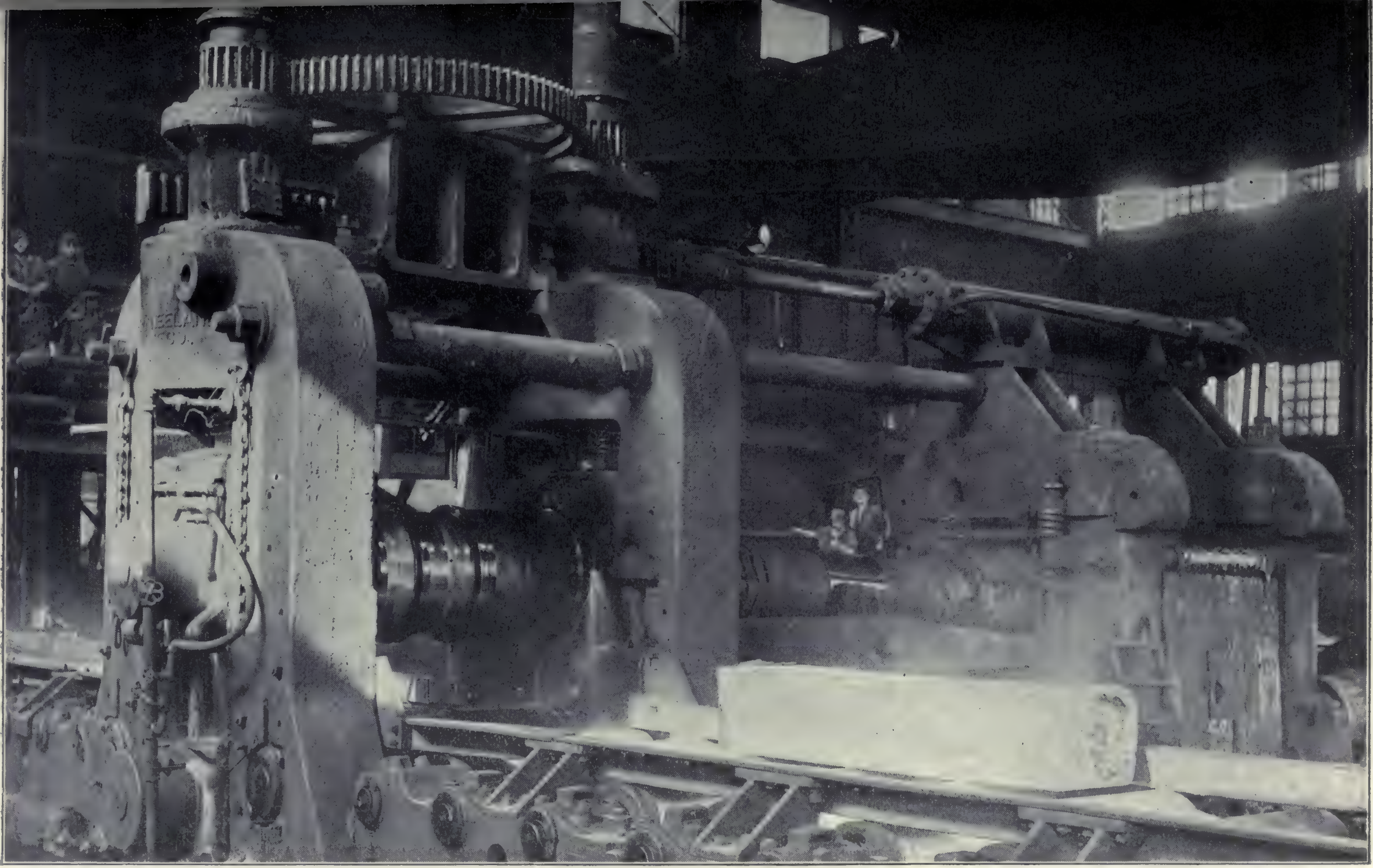
The pots are subjected to this terrific heat for two and a half to three hours, when the melter, by means of an iron rod, pushes the caps of the pots aside to ascertain whether the mass is melted. When melted it is still left in the furnace, in order to boil out any gas which might be held in solution. This is termed "killing" or "dead melting." Having been "killed," the molten steel is ready to be cast.

In preparation for this work of casting, the men wrap their legs with carpets, rubber, etc., and soak themselves with water. The cover is drawn from one of the holes; and the "puller out," dressed as above described, stands over the furnace or hole, and by means of a pair of tongs pulls the pots out, one at a time, carrying them to the moulds, which are standing in the casting pit at the end of the floor. There the molten steel is poured into the moulds, which stand upright. As a rule, the moulds are of one-pot capacity, but, if larger ingots are desired, larger moulds are employed, the metal being obtained from several pots. Care is taken that the stream from the two pots is not broken, the liquid flowing continually. If this is not done the result will be a defective ingot.

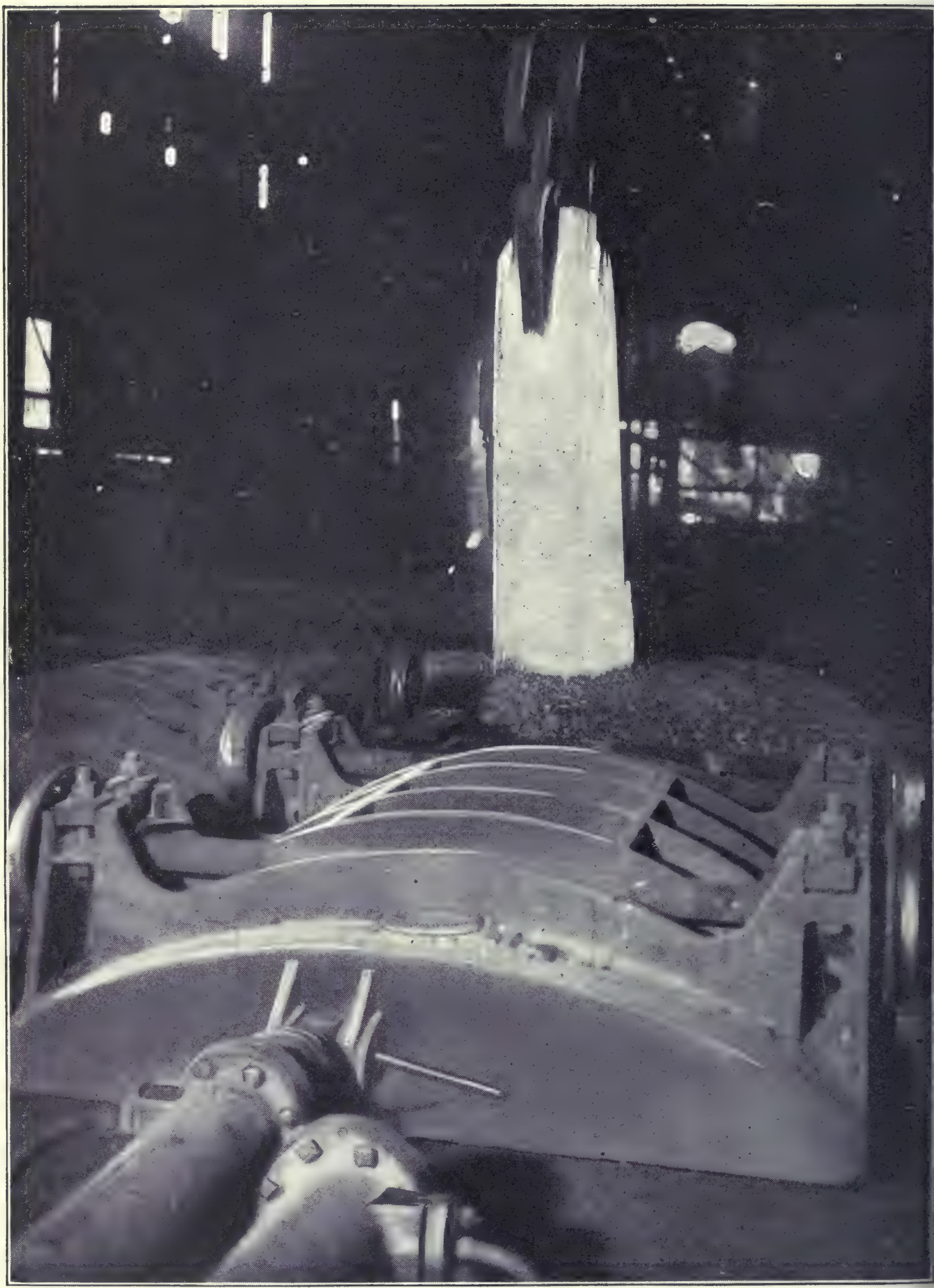
The pots, if in good condition, are refilled, and placed back in the furnace. When the steel in the moulds has solidified, the moulds are unfastened and the hot ingots drawn out, ready for another department.

The ingots are first taken from the casting pit or furnace to the "tempering" department. Here, by means of a sledge, the top of the piped end of each ingot is knocked off in order to expose the grain of the steel, thus permitting an experienced eye to ascertain the carbon percentage of the same. In mild ingots, and those of a shape or size that will not permit of the ends being removed, a small corner of the ingot is chipped off.

The formula being marked upon the ingot, indicating the grade and the percentage of carbon, the ingot is then either piled in stock or taken directly to another department. Unlike the products of other processes, many grades of crucible steel are first welded—hammered at a high heat—thus refining the grain and destroying many of the blow holes or gas holes. The steel is then



A Piece of White-Hot Steel, Weighing 6,000 Pounds, Entering the Rolls.



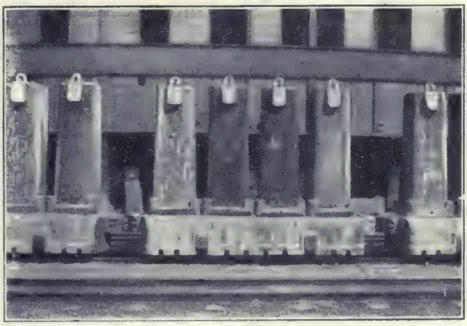
Raising a White-Hot Piece of Steel from the Soaking Pits by Means of a Powerful Electric Arm.

usually taken directly either to the hammer shop or to the mills. In either case the billets are reduced to the desired shape and size by being passed between rolls or under the rapidly moving dies of the steam hammer. The completed billets go to the "inspection house," where every bar of steel is examined minutely for all defects before being weighed, marked and shipped.

Open Hearth Process. The open hearth process furnishes about one-third of the steel used to-day. It has, for the past few years, been rapidly crowding Bessemer steel out of the market, as well as making great inroads in the fields formerly occupied by the crucible product.

The cause of this popularity, on the one hand, is that the stock, in many cases, is much sounder and gives better satisfaction than Bessemer—which naturally justifies the small additional expense. On the other hand, experiments have proven that the lower grades of crucible steel can readily be manufactured by the open hearth method without any visible difference except for the very much decreased expense.

The furnaces in which open hearth steel is made, vary in size from five to fifty tons' capacity, the modern ones being of the latter tonnage. In design they consist of an oblong brick structure alike at both ends. As in the case of the blast furnace, every particle of heat is caught and utilized. The air and gas, entering one end of the furnace and being thrown down upon the charge or "bath" by the curvature of the roof, dart across the furnace or hearth, making their escape through the ports on the opposite side, into the reheating chambers below. Thoroughly heating these, they finally pass up the stack. At regular intervals the air is allowed to circulate through the previously heated chambers prior to its entrance



A Car of Ingot Moulds.

into the furnace, the escaping gases entering and heating the opposite or cool set.

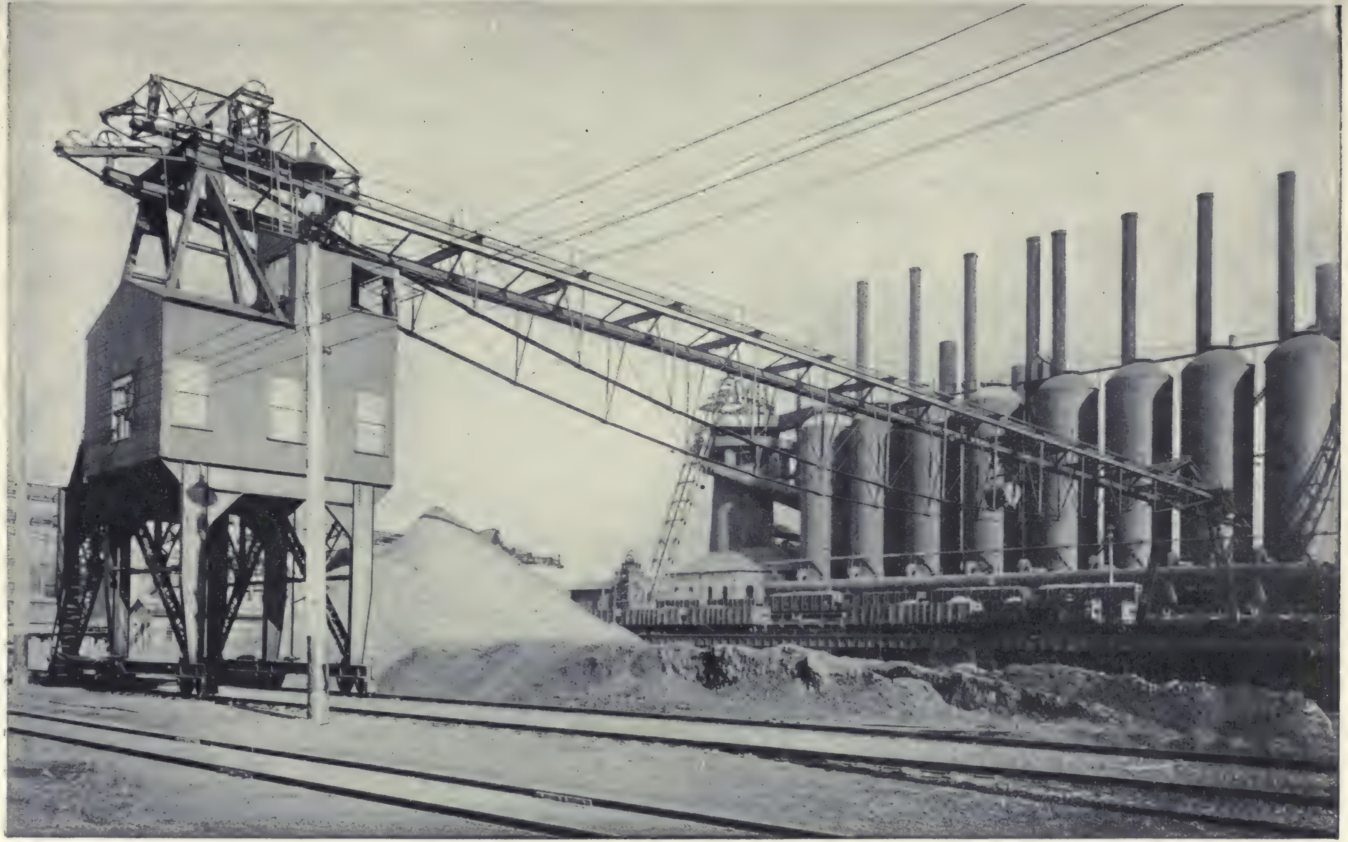
The bottom or hearth, which converges to one point in the center of the furnace, thus facilitating the tapping, is usually lined or covered with a special material, dependent upon the nature of the chemical reaction desired. If a basic reaction—one in which some of the foreign substances are eliminated or reduced—is desired, a basic lining is placed upon the bottom. This usually consists of dolomite, although magnesite, chromite, and lime have been used in a few cases. These materials are able to withstand the strong basic slag. In the acid process, where the phosphorus and sulphur are but little affected by the chemical reaction, a sand lining is usually employed.

During the past few years the open hearth plants have been entirely revolutionized. Whereas, in former days, the pig iron was charged in a cold state, to-day it is almost universally poured into the furnace in its maiden liquid condition, thus economizing in heat, labor, and time in melting.

By the present methods, the large ladles of iron are carried directly from the blast furnace to the mixer. They are next inverted, and their contents gradually poured in. Receiving as it does the products of the various casts of the blast furnaces, the mixer acts as an immense storage room, at the same time thoroughly mixing the several casts together, forming a uniform, homogeneous mass.

When the iron is required in the open hearth or Bessemer departments, the large furnace is swung down upon its axis, permitting the molten metal to flow through the mouth into the ladles standing upon the floor below.

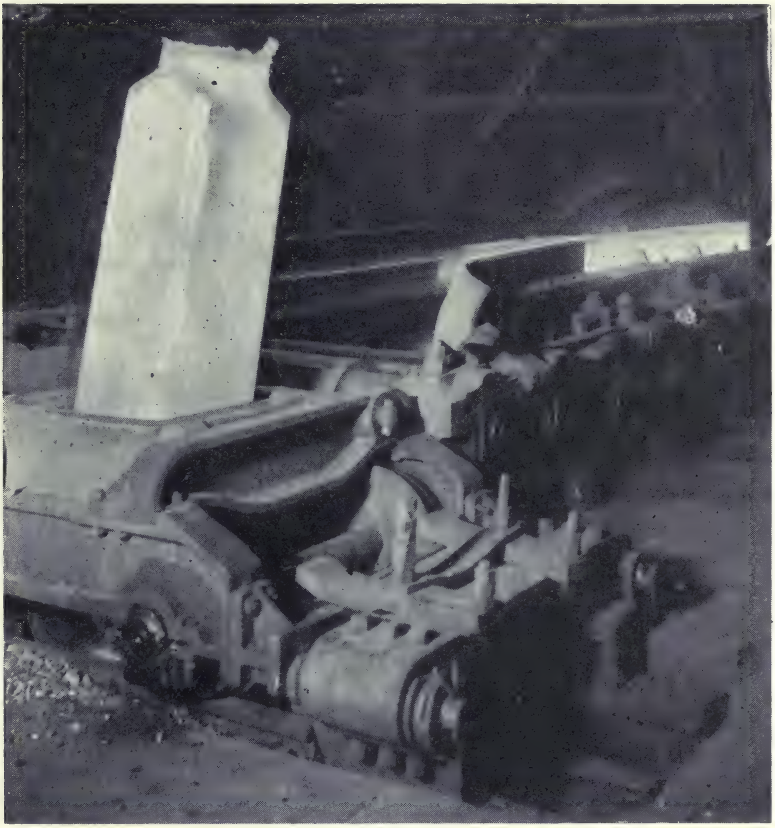
The open hearth furnaces are charged with all manner of scrap, old castings, rails, etc. As required, the desired quantity of each ingredient is placed in large cast-iron charging boxes similar in shape to a bath-tub, having a capacity of about 5,000 pounds each. These in turn are picked up and placed sidewise upon small, flat, narrow-gauge cars. When a sufficient amount to make a charge has thus been collected, the cars are drawn into the building, close to the front of the furnace. The furnace being ready for charging, the immense electric charging machine is brought into action.



ORE-STORAGE AND REHANDLING PLANT.
Duquesne Furnaces, Carnegie Steel Co., Limited.

By means of this wonderful device, one man, who manipulates the electric levers, can charge a furnace in less than twenty minutes, whereas, a few years ago, this was the work of several hours for a large army of men.

The "acid" process is practically no more nor less than a case of oxidation, in which the phosphorous and sulphur of the charge are not removed, but the steel continues to hold almost every atom of these ingredients as they were present in the iron, scrap, and ore. So the composition of the raw stock, as regards these two elements, must be positively ascertained; and if a low phosphorus and sulphur steel is desired, the charge must be regulated accordingly. On the other hand, the carbon, manganese, and silicon contained in the raw stock are oxidized.



White-Hot Ingot of Steel Being Delivered to the Rolls.

In this process the iron is usually charged first (though many plants charge the stock or scrap first), care being taken to insure its equal distribution over the bottom and on the banks or sides, the scrap being placed as evenly as possible over the iron, thus permitting the scrap to melt first and trickle over the hot iron, the latter being thus protected by the carbon and silicon, for which oxygen has a greater affinity than for iron.

After the metal becomes molten, a covering of slag forms upon the bath, due to the sand from the pig iron if the iron has been charged in the form of sand-cast pigs, and to the silica produced by oxidation. If the pig iron is free from sand and low in silicon, the slag will be very thin and of a basic nature, which would ruin the bottom. As a result, an addition of silica would have to be made. If the opposite, iron is usually added, which forms an iron oxide.

When the entire bath has been melted, iron ore is added at intervals, thus oxidizing the carbon, manganese, and silicon, and forming silica and oxide of manganese, which pass into the slag, while the carbon forms carbonic oxide which unites with the flames. The carbon thus causes the entire bath to bubble, which exposes the metal to the flames and keeps it hot. The metallic iron which is set free by the union of oxygen with the silicon and carbon, is dissolved by the bath.

At intervals a small cup is placed in the bath, and a test of the steel poured into small test ingots about one inch square in cross-section. After chilling in water, these ingots are broken, and the percentage of carbon is determined by the eye. If too high in carbon, the molten mass is oxidized still more; if too low, iron is added.

When the desired point is reached, ferro-manganese or some other recarbonizer is thrown into the bath, the furnace being tapped instantly and the steel permitted to run into the ladle. If this is not performed at once, the manganese will become oxidized through the intense heat of the flames and the slag.

Bessemer Process. Although there are two kinds of Bessemer steel, the "acid" and the "basic," the acid process is the one almost altogether employed, the conditions in this country proving adverse to the basic. In a nutshell, the Bessemer process consists in forcing a strong blast through molten pig iron, thus oxidizing the carbon and leaving the iron free from the same. In order to recarbonize it to the required percentage, ferro-manganese, coal, or Spiegel is added, while the molten iron is being poured into the ladle.

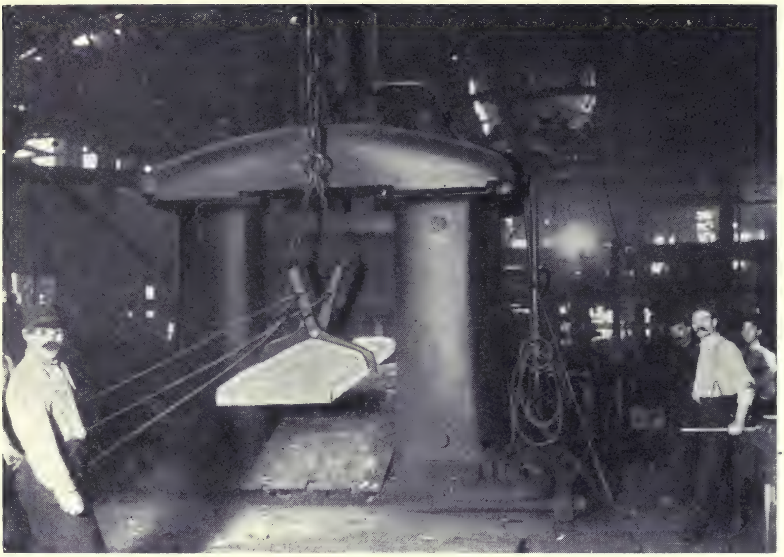
The furnace itself consists of an iron-covered, brick-lined, pear-shaped vessel suspended upon standards by means of two trunnion arms attached to the converter. By this means the vessel can be rotated almost seven-eighths of a revolution, thus permitting it to be placed horizontally on one side to be filled, then perpendicularly or vertically to be blown, horizontally on the opposite side be emptied, and upside down to permit the slag to run out.

The charge of five to twenty tons of molten iron, taken either from the mixer or from a cupola, being introduced, a strong blast of air of fifteen to twenty pounds' pressure per square inch is permitted to rush through one of the trunnions into the small chamber in the bottom of the vessel. From here it makes its exit into the interior of the vessel through the numerous small holes in the false bottom. At the same instant, the vessel revolves and points its mouth upward. Here it remains for several minutes, the first four or five minutes witnessing a flame of light yellowish-red color and a shower of glittering sparks. During this stage the uncombined or graphitic carbon passes into combined form, the silicon being oxidized to form silica, which unites with ferrous and manganous oxides to form slags. This change is accompanied by a rapid rise of temperature, the flames becoming brilliant, large, and of a very dense yellow color. The metal now boils, the agitation being due to the formation of carbonic oxide from the oxidation of the iron by the oxygen of the blast. During this stage the pressure of the blast is reduced.

The next stage in the process is signaled by the pale rosy hue of the flame, which becomes more transparent and less brilliant, together with the small number of sparks now issuing from the vessel.

These are signs that the carbon is nearly eliminated and the contents of the vessel almost ready for the last steps. When the flame drops, the vessel is at once turned down, and the blast shut off. Its contents are then poured into a ladle; and at the same time, a certain percentage of Spiegel or ferro-manganese is added, in either cold or liquid state, to recarbonize the metal to the required amount. The phosphorus and sulphur in the steel are practically the same as in the iron before blowing, the silicon, carbon and manganese having been reduced.

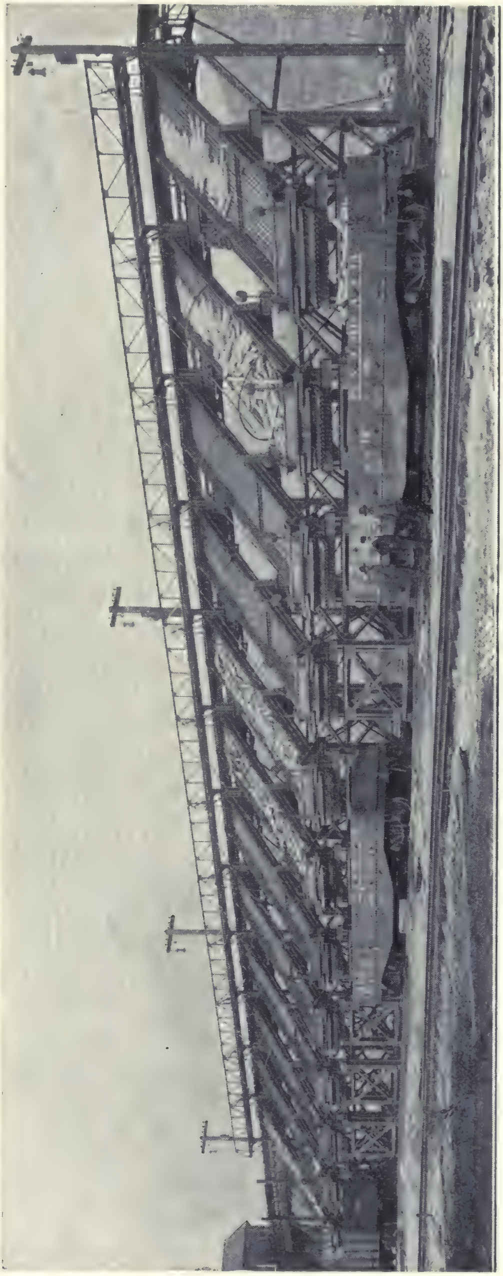
Quickly the vessel is turned over, filled, and the operation repeated; the ladle containing the molten steel being lifted by the hydraulic crane over a set of moulds, into which the newly made steel is poured. As soon as filled, a little locomotive carries the long row of cars upon which the freshly cast steel ingots and their moulds are resting, to the open yard beyond.



Shearing the Large Slabs of Steel While Red-Hot.

After the moulds have been filled with the molten steel, they are taken to the "stripper," which is usually next to the open hearth or Bessemer buildings. Here the cars containing the moulds are run under a large electric crane, which is so constructed that two arms fit over a projection on each side of the mould. As the mould is lifted, a central ram presses upon the top of the ingot, leaving the ingot upon the car, while the mould is picked up and placed upon a car located upon the next track.

From here the red-hot ingots are taken to the heating fur-



A New Method of Loading Steel Billets.

naces of a plate or "blooming" mill, where they are heated to a higher temperature for rolling. When of the proper heat, they are lifted out of the large furnaces by means of an electric crane and are carried to the table.

The latest method of transferring the ingots from the soaking pits to the rolls is by lifting them one at a time from the furnaces, as above stated; but instead of carrying them to the rolls by the crane, they are placed on end on a specially constructed cast-iron car operated by electricity. The car is then run to the end of the table, where a lever attached to the rail throws the body of the car towards the rolls, the ingot falling upon the table. The car then returns for another load.

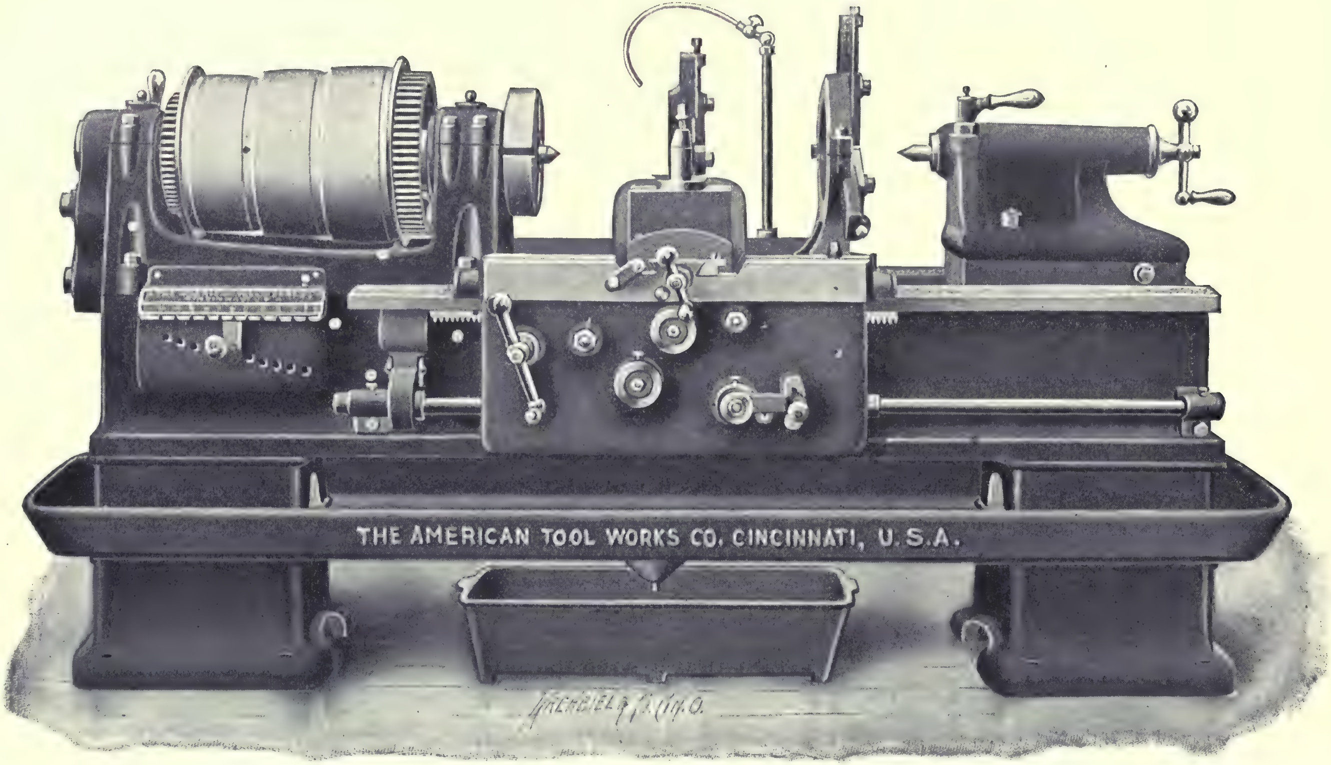
The rolls rotating, the ingot is advanced towards the large rolls through which it is to pass. Faster and faster revolve the small rolls, carrying the heavy solid block of steel towards the large rolls. Through these it goes, throwing its scale in every direction. The ingot having reached the other side in a somewhat flattened condition, the engines stop and reverse, the table again carrying the ingot between the rolls. Backward and forward it passes, each pass reducing its shape and thickness until of the proper dimensions, when it is carried between the powerful teeth of the shears which cut it to the desired lengths.

If billets are being made, they are conveyed as rapidly as sheared, by means of an endless chain, up an incline to the top ot the bins. Here is a long, narrow platform over which the chain travels. Along the side of the platform are the steel bins, with gates at both ends. The bottoms of the bins slant at an angle of sixty-five degrees from the chain to the ground. The billets, being carried up the incline and along the narrow platform, come in contact with the switch or upper door of the bin, which opens and allows them to enter. One after another they go tumbling down; and when the bin is filled, that gate is closed and the door of the next bin opened. When the billets have cooled, the lower gates are opened, and the billets fall into the cars beneath. Thus the steel is made, taken from the moulds, heated, rolled, cut and loaded, without the actual touch of man.

THE ECONOMY OF HIGH-SPEED STEEL.

In the finishing process in the machine shop, there has been a wonderful development, during the past few years, in the rapidity with which metal can be removed, as well as in the character of the surfaces obtained. For many years, tools made from cast steel, crucible steel, or tool steel (all these names referring to steel of practically 1 per cent carbon), were the only tools that could be employed in the machine shop for the removal of metal. The good old tempered steel tool did its work well, and, in spite of the development of other steels, it has not by any means been entirely superseded. One of the great advantages of the old carbon tool steel is that its manufacture and use have covered so long a period of time that the quality of the steel in the bar, and the results obtained by the shop smiths, have become very uniform.

Tungsten Steel. The first indication of improvement on carbon tool steel, in the line of ability to "stand punishment", was the introduction of the so-called "Mushet" steel, some fifteen or twenty years ago. This was a steel containing, in addition to the elements usually found in tool steel, a certain percentage of tungsten. The name "Mushet" was applied to the steel on account of the fact that R. Mushet of Sheffield, England, was the most prominent manufacturer of this grade. Tungsten steel has several peculiarities that distinguish it from carbon steel. It is an extremely hard steel, and cannot be easily forged. It has the peculiar property of being always hard; that is, when heated and forged, it resumes its hard condition after slow cooling. Dipping it when at a red heat, in water, will almost invariably cause the steel to fly in pieces. On the grinding wheel, tungsten steel shows a dull red spark entirely different from the spark given off by carbon tool steel. Owing to its permanently hard condition, forging and grinding were the only processes by which tools could be shaped, and consequently this steel was used for lathe and planer tools almost exclusively. During recent years, methods have been found for annealing tungsten steel to a limited degree, so that its use is no longer limited by its hard and brittle nature. Another point of difference that calls for consideration is that of price.



AMERICAN HIGH-SPEED MANUFACTURING LATHE.

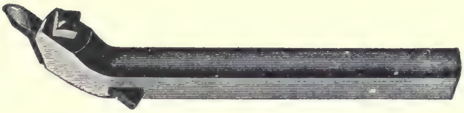
The best carbon tool steel costs about fifteen cents per pound, while the tungsten steels are worth about forty-five cents.

The results obtained by the use of tungsten steel were of great importance. The steel would stand a very much higher temperature than carbon steel before losing its edge. Therefore—for "roughing" cuts, especially—it was found that considerable time could be saved by cutting at a higher rate of speed. It was discovered, however, that the tungsten steel would not maintain a clean, sharp-cutting edge suitable for light finishing cuts, so well as would the carbon steel. Therefore the use of tungsten steel was limited almost entirely to the roughing cuts.

Heat Treatment for Tool Steels. Several years ago a process of heat treatment for tool steels—called the "Taylor-White" process—was responsible for another step forward in the rapidity of shop operations. While this process was more particularly adapted to a certain brand of self-hardening steel, it was claimed that its use would improve the heat-resisting quality of any good brand of tool steel. It would be well to note at this point that the whole matter of increased speed of cut seems to hinge on the temperature at which the tool will lose its edge. Owing to the fact that the Taylor-White process was not generally understood, its use did not become very extended, but it paved the way for the introduction of the modern high-speed steels, which depend for their successful operation on a heat treatment somewhat similar to that employed in the Taylor-White process. There have sprung up a multitude of brands of high-speed steels, which are designated by various names, such as "air-hardening", "self-hardening", "high-speed", etc. The chemical composition of these steels is generally not made public, and there has been a great deal of mystery attached both to the material itself and to its method of treatment. This has prevented a more rapid introduction.

High-speed steel can be annealed, and cutting tools of all kinds can be made from it. In this it differs from the tungsten steel. It is also higher than the latter in price, costing about seventy-five cents per pound. To speak of the economy of high-speed steel at such a price implies, of course, that the results must fully warrant the outlay. It is believed that the judicious use of high-speed steel is in reality economical. By judicious use is meant use where the results are clearly superior to those obtained by the employment of the cheaper and slower working steels.

On account of the high price of these improved grades, it has been found economical to use the steel in small sections which can be carried in a case-hardened mild-steel holder. Typical examples are shown in the accompanying illustrations. While these holders are very handy, and certainly save large amounts of costly steel, still they cannot be made as rigid as a solid forged tool; and, for the very heaviest work, a tool forged from the solid is still preferred. High-speed steel, however, is very brittle, and, if forged solid, should be carried out to the cutting edge in as large a section as possible. If used in a holder, it must be supported very nearly out to the cutting edge.



OFFSET TOOL HOLDER (LEFT HAND).

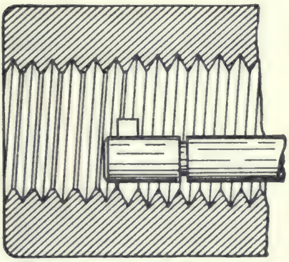
Holders for this costly steel usually provide means of clamping by a set screw. Some method of doing away with the vibration inseparable from a screw is desired; and it has been suggested and proven to be good practice to solder or braze small pieces of high-speed steel onto soft-steel shanks. This has in many cases proved very satisfactory.

The Test of Results. There have been so many extravagant claims made in regard to results alleged to be accomplished by the use of high-speed steel, that many men have concluded that this steel could not possibly fulfill them. As a matter of fact, in many cases cited, it cannot. Actual results, however—sufficient to establish the economy of these steels—can be obtained in abundance, and a few general figures on relative speeds may prove of value. With ordinary carbon-steel tools, an average figure for the cutting speed would be about 20 feet per minute for mild steel, 30 feet per minute for wrought iron, and 40 feet per minute for cast iron. These figures, of course, are merely approximate, but they fairly represent

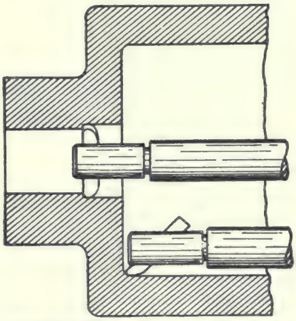
OFFSET TOOL HOLDER (RIGHT HAND).

average practice. By the use of tungsten steel, the speed for roughing cuts was increased about fifty per cent, while heavier cuts, also, could at the same time be taken. The later high-speed steels, however, show great improvement over these figures, the speed for roughing cuts being increased to about 50 feet a minute for mild steel and wrought iron, and 75 to 80 feet per minute for cast iron. Finishing cuts, especially for mild steel, can be taken at rates which appear to be little short of marvellous, a speed of from 150 feet to 200 feet per minute being not uncommon in the finishing of mild steel.

One of the peculiar things connected with the development of high-speed steel, has been the simultaneous development of grinding. The process of grinding has no place in this article, but it may be noted that the high-speed steels are being extensively used for roughing cuts, while the finish is obtained by grinding. As an instance of work of this character might be cited the turning of cast iron at a cutting speed of 75 feet per minute—depth of cut $\frac{1}{8}$ inch, with a feed of $\frac{1}{4}$ inch per revolution, leaving $\frac{1}{32}$ inch over the correct size at the bottom of the groove. The finish obtained by grinding is superior to, and more rapid than, that secured by fine turning, filing, and polishing.



Tool Cutting a Thread.



Double-Ended Cutter Roughing Out Cored Hole. Also Angle Cutter Boring and Facing End.

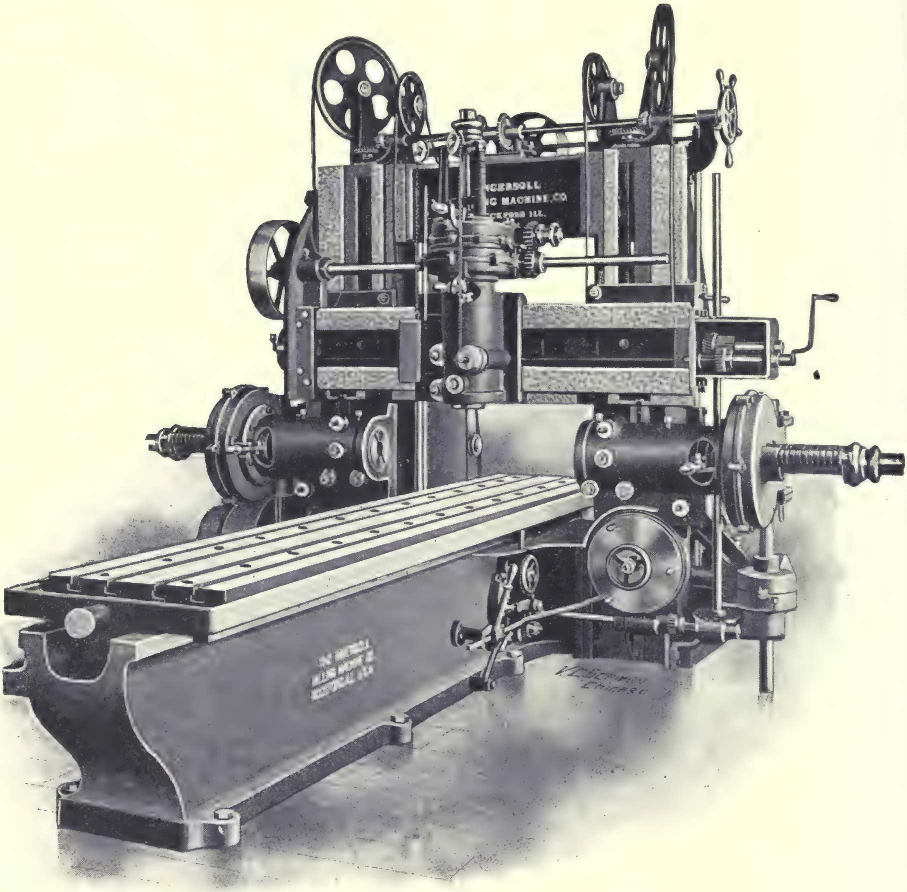
People have become discouraged—in some instances, possibly, disgusted—with high-speed steel, on account of the oft-prevailing tendency of human nature to wish to get something for nothing. There are many brands of this steel, and the methods of working, especially as far as the heat treatment is concerned, are as numerous as the steels themselves. Nearly all steel salesmen, even if they do not insist on leaving a sample of their steel, are perfectly willing to do so; and the result is the tool room soon acquires a collection from which the identifying marks are almost sure to be lost, whereupon there is trouble for the tool dresser and the machinist. It is not intended by this to advise the exclusion of new materials and processes, but more particularly to recommend keeping the experimental and the commercial ends of one's business separate and distinct from each other. It is well to try thoroughly all brands of steel offered; but it is not wise to have more than one brand for shop use.

The steel salesman, also, in numerous instances, is inclined to make claims for his particular brand, which claims, in many cases, cannot be substantiated. This does not imply that the results will not show a distinct advantage over the old carbon steels. The purchaser should not expect to obtain results fully equal to those claimed by the agent, the claims of the salesman being generally based on short laboratory tests, and sometimes, it is to be feared, colored to suit the prospective purchaser. If a substantial saving in time can be made, there is economy in the use of high-speed steel, and the fact that still better results than this are claimed, does not prove that its use is not economical.

There is an economy in the use of this steel, which, while it may be attributed to the material, is in a sense not directly concerned with its use. It is a well-known fact that so simple a matter as speeding up the shafting has a tendency to quicken the life of the whole shop. This is true not only as regards the actual output of the machines; but it also actually quickens the physical movements and mental grasp of the workmen themselves.

In a recent address before an engineering society, a speaker used this expression, "High-speed steel is developing high-speed machinists." This remark is strictly true; and, although the introduction of this steel will be opposed by the slothful workman, its influence upon the great majority of men will be distinctly beneficial.

To sum up in a word, the economy of high-speed steel may be said to comprise saving of time in the machine operation; better mechanical results, especially if we include the simultaneous development of grinding; and finally—perhaps the most important of all—the quickening, physically and mentally, of the workman.



36" x 36" THREE HEAD MILLING MACHINE
Ingersoll Milling Machine Co.

FLAWS IN CASTINGS

Thermite, which is mainly a mixture of finely divided aluminum and iron oxide, is known to go on burning spontaneously after it has been ignited at any point. This fact has been utilized by Dr. Goldschmidt in connection with a number of further discoveries and inventions constituting the body of quite a novel branch of chemical science to which the name *Alumino-thermics* has been given. In its spontaneous combustion, thermite produces temperatures as high as about 3,000° C. The iron is thus liberated in a pure state, free from carbon, a slag of aluminum oxide (the so-called artificial corundum) being formed at the same time. The use of thermite for obtaining castings free from pores and flaws is based on the fact that the material is able to burn without requiring any supply of gases, and without giving rise to the formation of any gaseous products in the reaction.

The action of thermite on metallic baths is a triple one:—In the first place, the metals produced by the reaction are alloyed to the bath; second, the heat of reaction of the thermite is transmitted to the bath; and third, in the case of a suitable application, a lively intermixing of the metallic bath will take place. The thermite is introduced into the liquid metal in a sheet-metal box, so as to produce the reaction below the surface of the fused metal. In the case of cast iron, titanium thermite is used, which is a thermite containing, in addition to aluminium and iron oxide, some titanium oxide intended to supply to the fused metal a certain amount of titanium, when any one of the three effects pointed out above will be produced.

A box filled with titanium thermite (Fig. 1) is fixed by a wire to an iron bar, the latter being fitted into a centrical hole in the box. The bar used in this connection should be fairly free from rust and perfectly dry. After the box and the bar have been reheated to the temperature of the hand, they are thrown into the metallic bath by a workman whose hands are protected by gloves against the radiating heat from the surface of the fused metal. During the reaction, the bar is kept within the metal as motionless as possible. After the thermite box has been dipped into the bath, the reaction will take place instantaneously, lasting about 1 to 1½ minutes in regular course; it is manifested externally by a lively bubbling of the bath, resulting in a mixture so intimate that it would be impossible by the use of any other agent. This intermixing is, of course, attended with a material improvement of the iron itself, any differences due to the variations in the iron from different stages melted together being compensated for. The iron expert will notice at once in the liquid metal, the influence exerted on its condition by the thermite reaction. In fact, the jet flowing from the cupola furnace onto a pan is perfectly opaque; while in the case of the iron undergoing the thermite reaction, the jet issuing from the pan has a clear, translucid appearance. The effect may be noticed also from the aspect of the breaking surfaces of iron treated with thermite; in fact, the grains of the iron are much finer, its structure is rather dense, and the iron has a remarkable polishing capacity, any disturbing graphite films becoming so small as not to be noticed by the naked eye. In the case of the amount of thermite being sufficient, the increase in temperature produced by the reaction is materially higher than a simultaneous unavoidable loss by heat radiation; this increase, as well as the reduction of the ferro-oxides dissolved in the bath, will materially

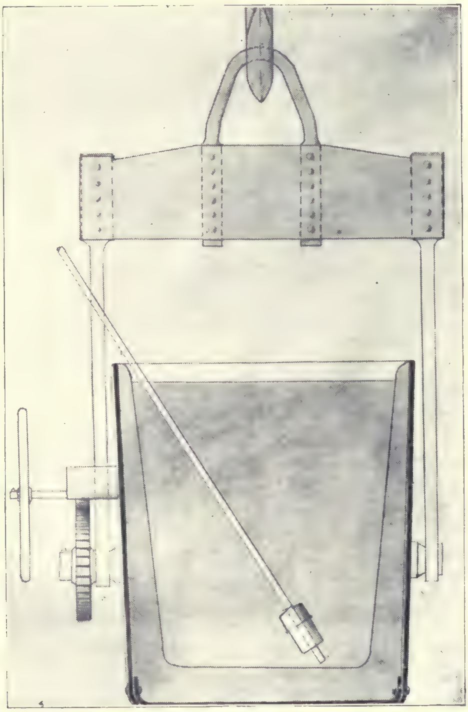


Fig. 1. Casting-Pan with Titanium Thermite Box Immersed.

augment the liquidity of the molten metal. Finally, the cast iron will receive a certain addition of titanium from the reaction. It is not safe to state whether the addition of titanium, or the mechanical effect of the reaction, is mainly operative in freeing the cast iron from the gases dissolved. It is, however, a fact that the castings are freed from any gas they may contain. Metal surfaces that formerly would spit continuously, become quite motionless after the reaction has been produced.

A further property of titanium is the fact that it will fix nitrogen. In the case of the liquid iron containing even small amounts of titanium, the latter will decompose the atmospheric air, fixing the nitrogen it contains; while the oxygen is made to form a compound with iron, which is dissolved in the liquid metal without necessitating any further reaction. This accounts for the perfect absence of pores in cast iron treated with thermite. The effect of thermite on larger steel castings in preventing the formation of flaws, is quite analogous. The thermite used to this effect is a special kind known as "flaw-thermite," which is made to act only during the casting process.

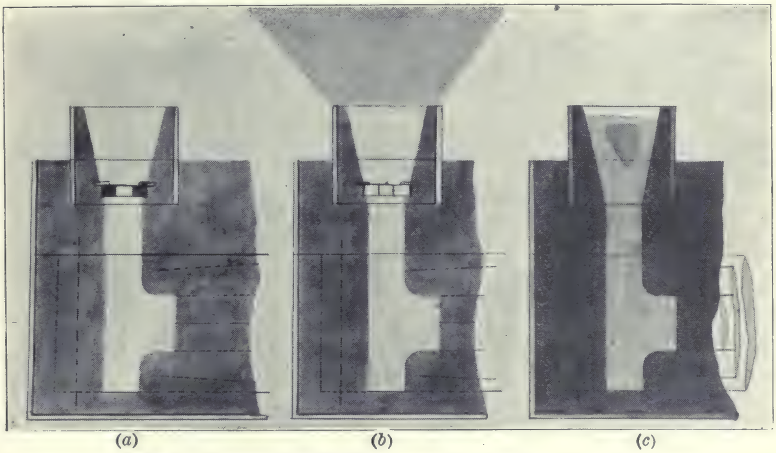


Fig. 2. Use of Flaw-Thermite in Making Steel Castings.
(*a*) Before, (*b*) During, (*c*) after casting process.

In the steel foundry, the formation of flaws underneath the rising funnel is known to be a serious drawback. The steel rising from the interior of the casing into the rising funnels had to traverse the whole of the mould, giving off on its way a large portion of its own heat to the colder walls of the mould. Even in the case of the cross-section of the funnel being very great, the steel filling the latter would therefore in many cases be solidified more rapidly than the steel in the interior of the casting, thus preventing any metal from the funnel returning to the interior of the steel casting to fill up any hollow formed during the solidification. This would result in flaws being formed in most cases immediately beneath the rising funnel.

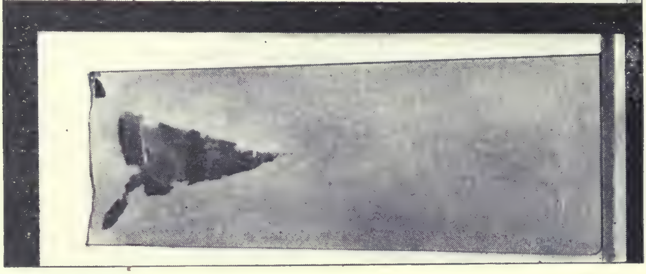


Fig. 3. Ten-Ton Block of Steel, Cast without Use of Thermite, Showing Serious Flaws.

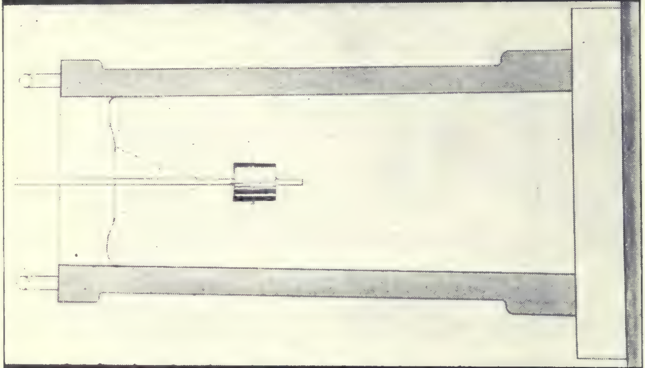


Fig. 4. Diagram to Illustrate Thermite Process of Preventing Flaws in Castings

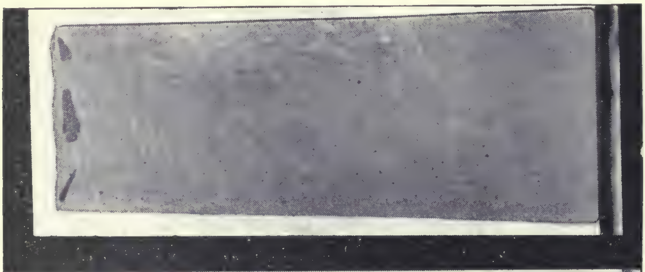
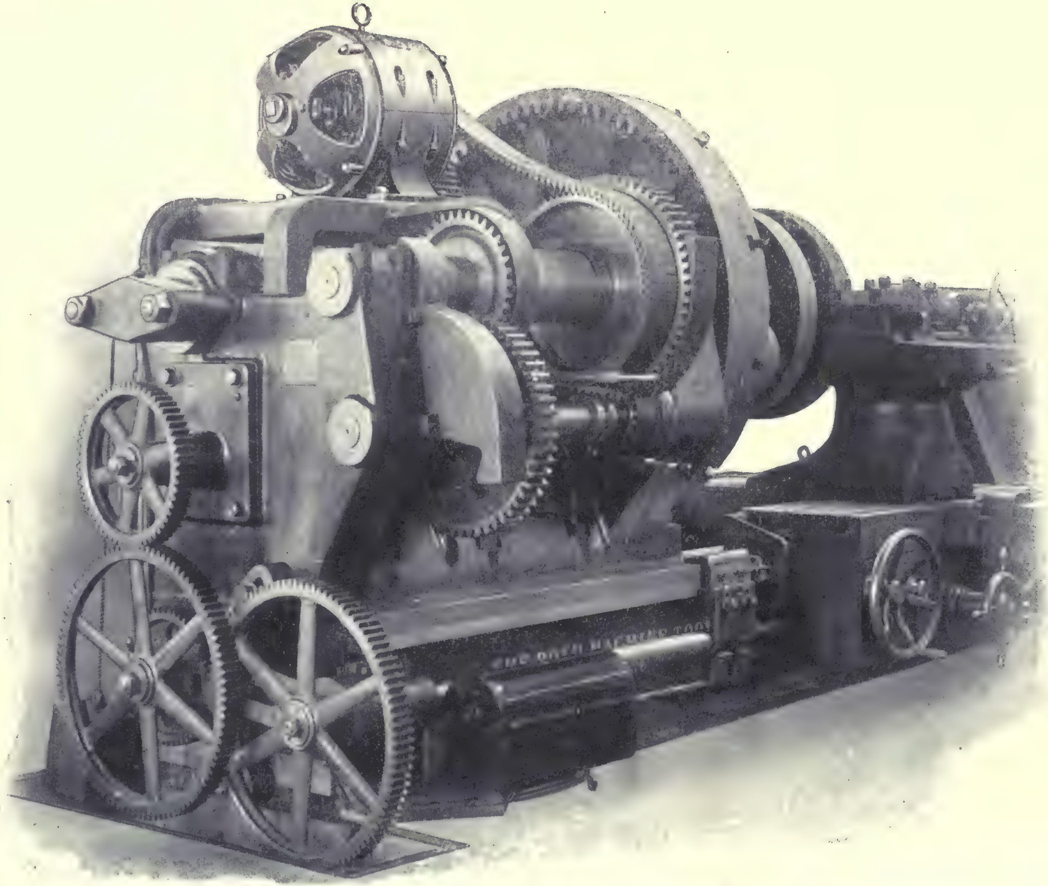


Fig. 5. Ten-Ton Block of Steel.—Flaws Reduced to Minimum by use of Thermite in Casting.

Instead of the thermite welding process used in many foundries to fill up these flaws, it is much more practicable so to control the solidifying process of steel castings by the use of thermite, as to *prevent the formation of flaws.* Fig. 2 shows a simple way of effecting this. On the left of the figure, is shown a portion of a steel casting mould, into the rising funnel of which a box containing thermite has been fitted before the casting process. The steel rising from the mould into the funnel will traverse the central hole of the thermite box, igniting the contents of the latter. As will be seen from the middle part of the figure, the thermite is burned while the steel fills up the funnel, *i. e.*, beneath the surface of the liquid metal, thus driving the whole of the contents to an extremely high temperature. The steel in the funnel, therefore, remains in a liquid condition for a longer period than the one within the casting. As shown in the third part of the figure (*c*) any flaws will now be formed at a place where they are quite harmless—namely, in the interior of the rising funnel.

Another use of thermite in boxes is illustrated by Figs. 3, 4, and 5, where the manufacture of forgings free from flaws is illustrated. In Fig. 3 is represented the cross-section of a forging block made after the ordinary process. As will be seen, the flaws are developed greatly, reaching 42 per cent of the depth of the block. If a box of thermite be introduced into the block (See Fig 4) at so late a moment as to allow of the steel throughout the block passing to a plastic condition, the thermite reaction is started instantaneously, when the mass of the block is again liquified throughout; and, the steel filling up any flaws already formed, a funnel of different size, opened upwards, will be formed. The latter should be filled up with liquid steel kept ready for the purpose, whereupon, the thermite slag rising to the surface, a practically perfectly dense block, having only small flaws at most on the upper edge will be formed, as shown in Fig. 5. Steel blocks of enormous weight have thus been manufactured free from flaws.



72-INCH LATHE DRIVEN BY 15 H.P. THOMPSON-RYAN MOTOR.

850–1750 Rev. per Minute.

Ridgway Dynamo and Engine Co.

ELECTRIC LIFTING MAGNETS

One of the most interesting modern applications of electricity is its use in connection with electromagnets for the lifting of loads. An apparently immaterial alteration in the construction of cranes and traveling platforms in foundries, steel works, rolling mills, blast furnace plants, etc., where loads had formerly to be lifted by hooks, has resulted in a saving of labor and in an increased efficiency of operation wherever electromagnets have been resorted to in the course of the last few years.

Whereas American constructors, who first devised this use of electricity, employed electromagnets with open coils, Belgian firms, and in the first place the International Electric Engineering Company of Liége, prefer enclosing the coils completely, so as to enable them to be used without any inconvenience in the open air, while obtaining an efficient mechanical protection against any kind of mechanical injury to which they are liable to be exposed.

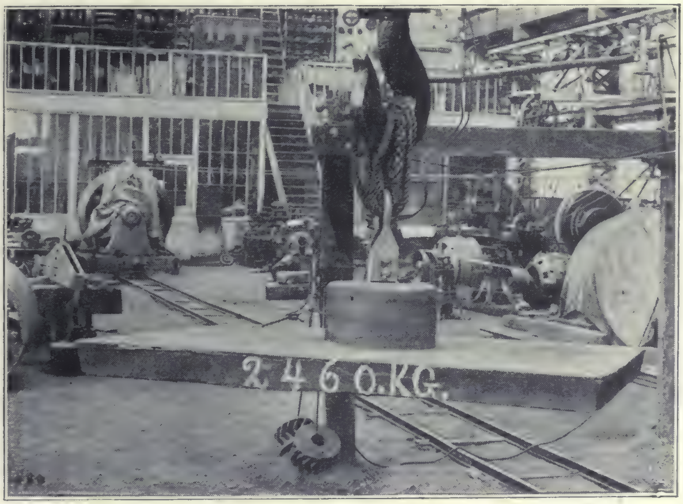


Fig. 1. Single Magnet.

It may be said, however, that the construction of such electromagnets for lifting heavy pieces of iron and steel has always offered serious difficulties and that only a few constructors have been really successful in designing a satisfactory type of apparatus. The International company, who made a specialty of the construction of electrically driven cranes for use in iron and steel works, etc., paid much attention to the problem of lifting magnets, and eventually obtained rather satisfactory results in this line By the courtesy of that company we reproduce illustrations of a few of its magnets.

One of the main advantages afforded by electric-lifting magnets is the saving just referred to in time and manual labor. When attaching the load to the hook of the crane by means of ropes or chains, the services of at least two men were required for the handling of heavy pieces. Now, the electromagnet does away with both the ropes and the men to fix them, all the operations being carried out by the driver of the crane. He it is who lowers the magnet on to the piece of metal to be lifted and excites it by means of the switch which is placed in his cabin. When the

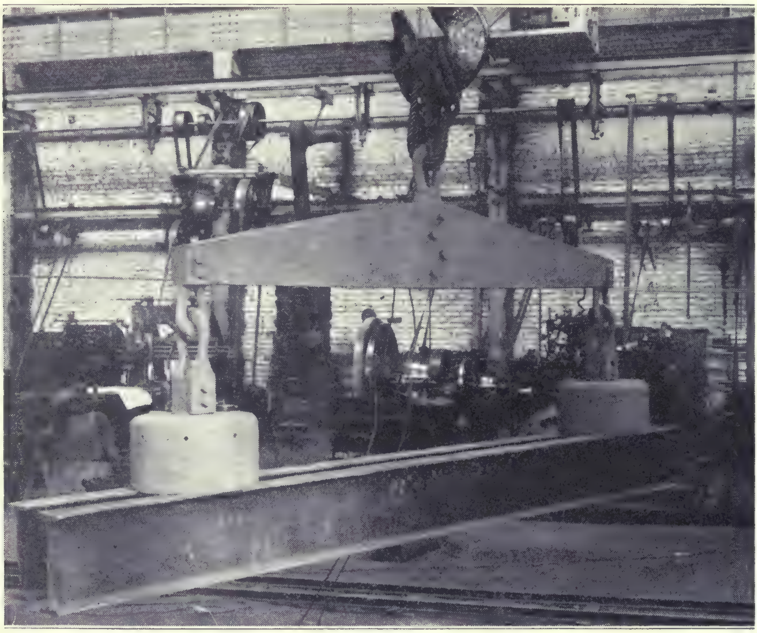


Fig. 2. Double Magnet for Lifting Girders, etc.

load reaches the place where it is desired to drop it, the driver lowers the magnet and finally cuts off the current.

The time occupied in picking up the load with magnets is very short; in fact, two or three seconds are quite sufficient; so there is an enormous saving in this respect, while the performance of a given crane is materially increased, the result being that the works can be run with fewer cranes.

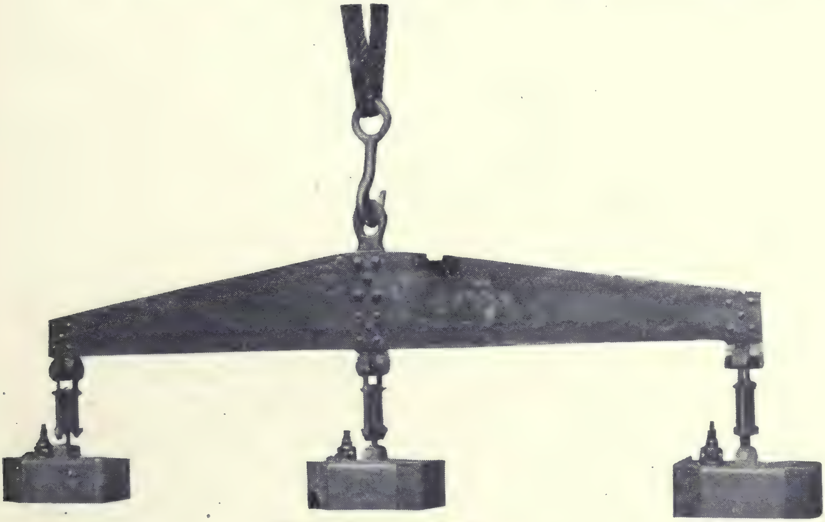


Fig. 3. Triple Magnet.

The greater consumption of power which is doubtless connected with this additional use of electricity is quite an insignificant item, as a magnet capable of suspending two and one-half tons requires only about 750 watts.

The International company's magnets are mostly of two kinds, represented in Figs. 1 and 2 respectively. The kind seen in Figs. 1 and 3 serves for the handling of sheets and ingots, while the other type is used in connection with girders and the like. The first type is an electromagnet where the magnetic circuit is formed by an internal core and an external bell-shaped cover and is com-

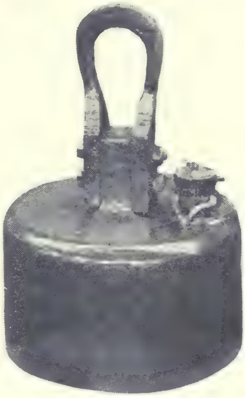
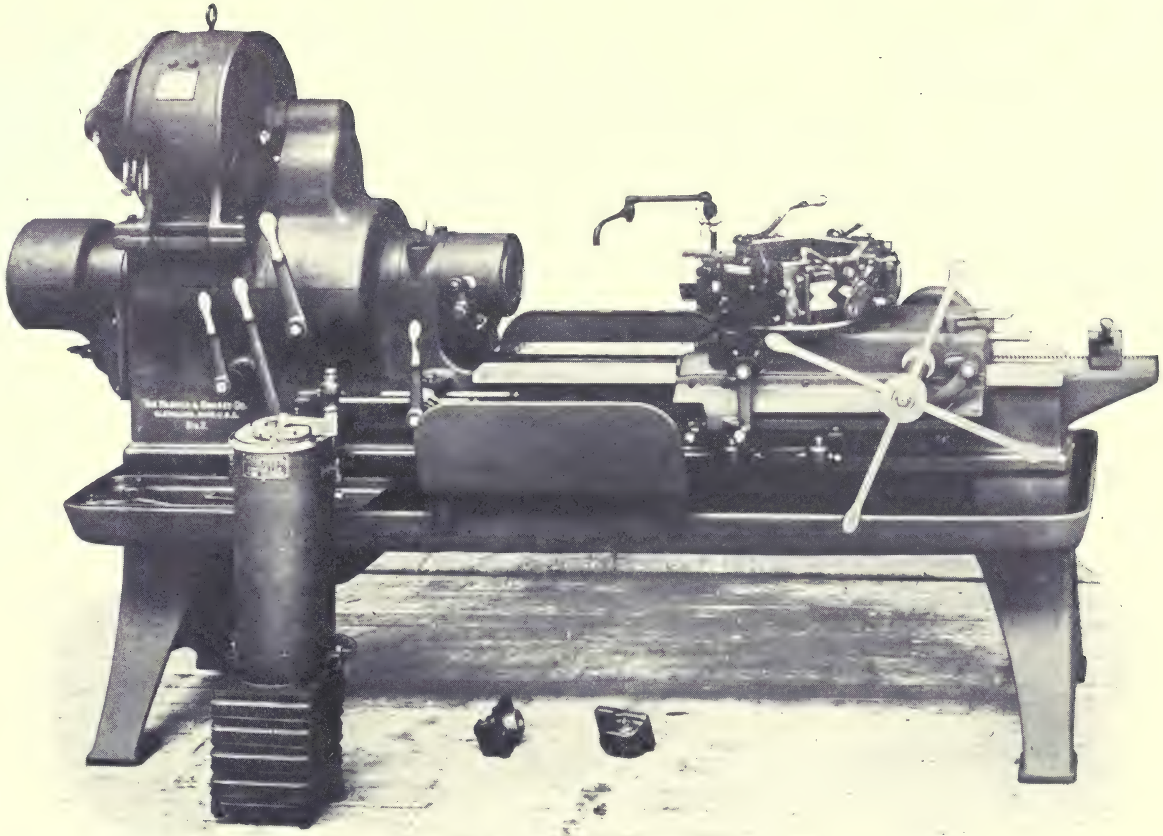


Fig. 4. Electric Lifting Magnet.

pleted by the piece to be lifted. The other type seen in Fig. 2 is composed simply of two single type magnets fixed one at each end of a beam, suspended in the center from the crane hook. Fig. 4 shows the magnet as it appears when ready for fixing to the crane.

It may be mentioned that the magnets can be used also for lifting very hot pieces of metal, which makes them especially useful in foundries, rolling mills, etc. The current is supplied by two parallel wires extending the full length of the crane, connections to them being made by contact pieces fixed to the crab.



WARNER AND SWASEY TURRET LATHE WITH BALANCED THREE-WIRE EQUIPMENT.

Controller within Easy Reach of Operator.

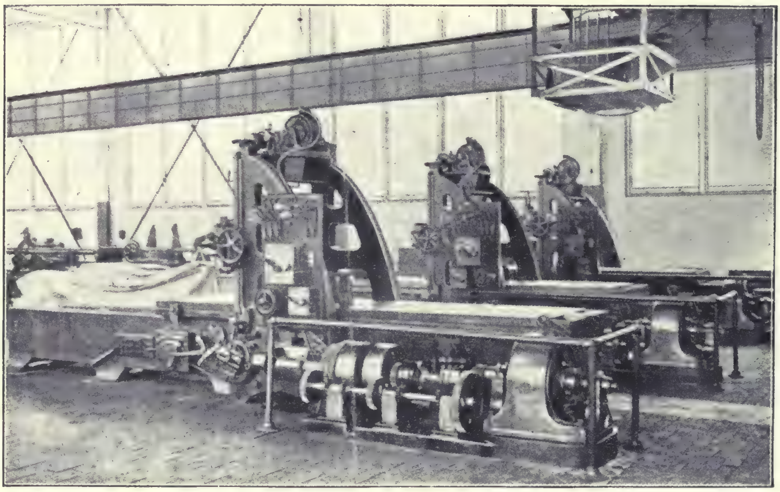
MAGNETIC CLUTCHES

Since the advent of individual motor-driven machine tools, the successful application of magnetic clutches has made possible the operation of an entire machine shop concerning which it may be said—"There is neither line shaft, counter-shaft, nor belt therein."

The utilization of magnetic clutches in driving planers has made a decided difference in the economical operation of these machines, as it has increased the output by making possible a variety of speeds, the operator being enabled to change the speed to suit the work. The planers can be run at a much higher speed than formerly, as there are no belts to slip or burn, and, in securing high speeds on belt-driven planers, the belts would have to be made so heavy that considerable difficulty would be experienced in shifting them. Magnetic clutches, moreover, are very positive in their operation, so that it is possible to work very close to a shoulder or offset. A test was made on a 96-inch planer by setting it so that it would run the tool within 1-32 inch of a shoulder; one hundred strokes were made, and the reverse did not vary enough to allow the tool to touch.

In using these clutches, a machine can be thrown out of action from any number of points at any distance, depending on the number of switches placed in the clutch circuit. The current required by the clutches is surprisingly small considering the amount of power transmitted; on a certain planer it required only .75 ampere to pull two cuts through cast iron, each being 3-32 inch x 2½ inch, at the speed of 14 feet 3 inches per minute. This cut does not really indicate how much the clutches will pull as it is just the ordinary work accomplished by the machine mentioned. One of the clutches in use on this planer was tested by putting a strain of 60,000 pounds on it in an attempt to separate the armature from the magnet. How much more than this it would have successfully withstood, cannot be stated, as the parties making the test would not put any greater strain on their apparatus. This test was made on a 33-inch clutch.

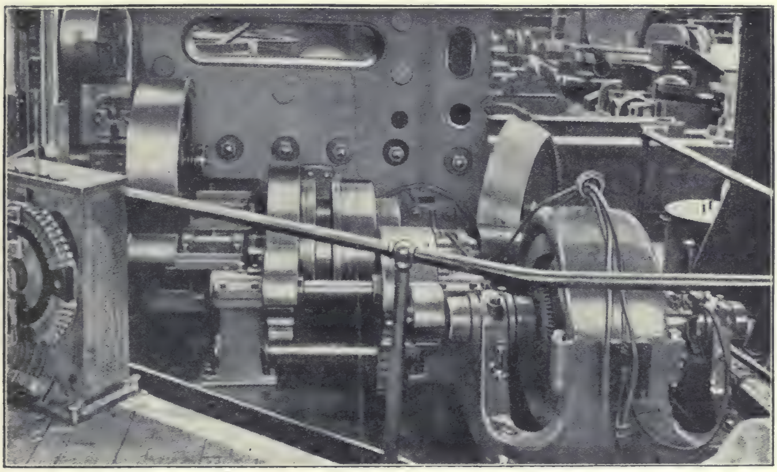
In the accompanying illustration of a 36-in. x 36-in. planer, it will be noticed that there are three gears of different diameters on the left-hand clutch, and there is a field rheostat on the side of the housing of the planer; this will give three different speeds by changing the gearing, and a variety of intermediate speeds from field regulation on the driving motor. The driving member, in this case, is an ordinary shunt-wound motor driving a pair of clutches through what is known as a "five-gear reverse." The right-hand clutch controls the return of the platen; and, as the driving and driven gears are of about the same size, a very high speed is obtained.



Pond Planers, 36 x 36-inch, Operated by Magnetic Clutches.

A magnetic brake is shown at the right of the clutches, and is a very important adjunct to this equipment; should the planer be working very close to the limits of its stroke and the power fail, the platen cannot drift beyond safe limits, as the brake will set and stop the machine instantly. The brake also comes in very handy in setting up work, as the operator can depend upon it to stop the instant he opens the switch.

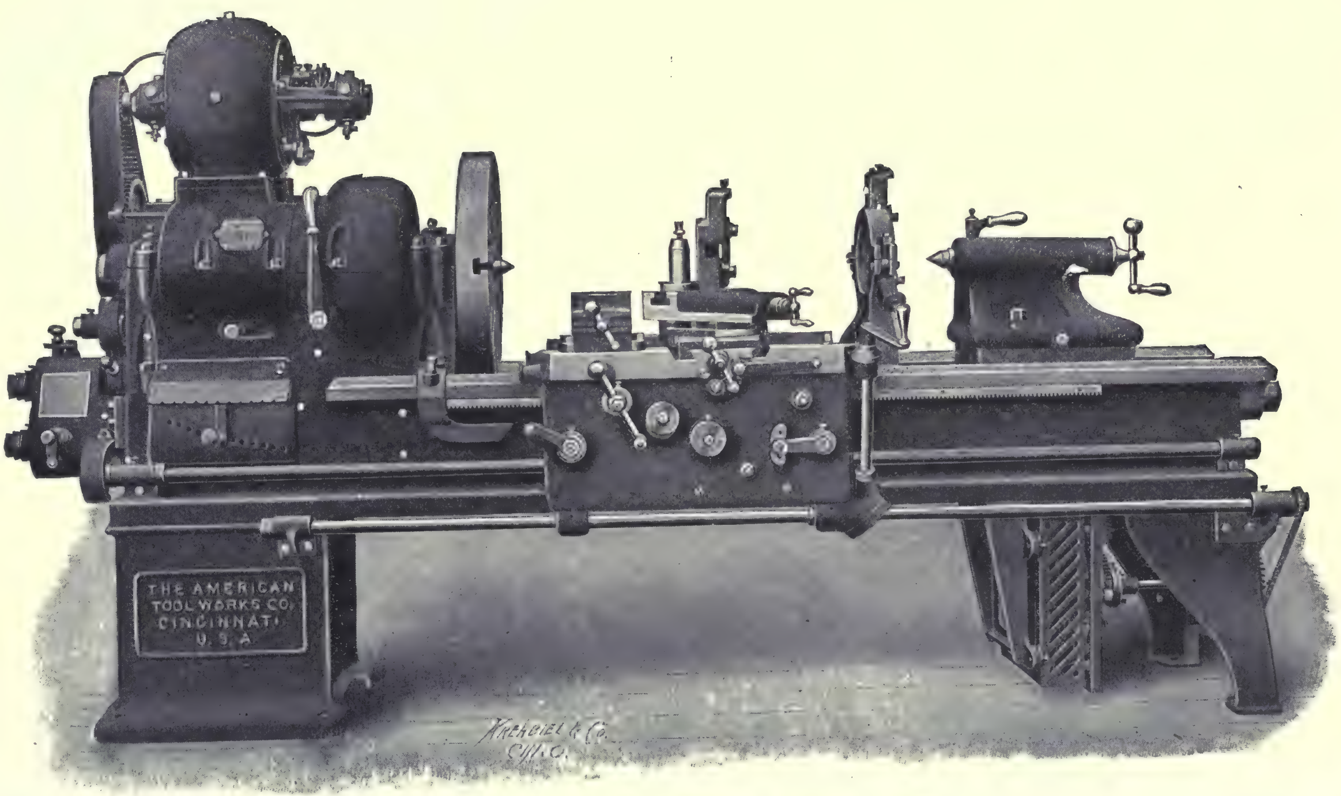
Magnetic clutches have been very successfully applied to machines for tapping out pipe fittings; in these machines the taps are run in a certain distance, and then reversed to run them out. The tapping machines run at such high speeds that ordinary mechanical or friction clutches will not stand up to the work, or, if the clutch is made heavy and positive enough to do the work, it soon tears the machine to pieces; every time the mechanical clutches would reverse, the jar would affect the entire shop. Since magnetic clutches have been applied, however, the machines reverse so noiselessly that it is necessary to watch them closely to tell when the reversing occurs. The line shafting in shops and mills can be connected up in sections by using magnetic clutches; and any section can be instantaneously disconnected by snapping a switch located anywhere in the shop, or from any one of a number of points, as might be desired.



A 72 x 72-inch Detrick & Harvey Planer Operated by Magnetic Clutches.

Magnetic clutches can be so arranged in connection with counter-shafts that, instead of using a belt shifter, a small switch fastened to the machine is all that the operator will have to move. By this arrangement the counter-shaft does not have to be located directly over the machine, as is the common practice at present. This system of clutches is almost ideal for use in cotton or woolen mills, where it is absolutely necessary to stop a loom instantly should a thread break in the weaving. It requires very little force, and but an instant of time, to set or release a magnetic clutch; and it does not require any more exertion to set a large clutch than it does to set a small one; in either case it would require about the same effort as to switch on or off an ordinary incandescent lamp.

Residual magnetism has been the great bugaboo in most of the attempts to use magnetic clutches, but this source of trouble has been eliminated so that their positive operation can be depended on. There is hardly a limit to the amount of power that can be transmitted; and, considering the ease with which magnetic clutches can be operated, it seems that there is a great field for them when they come to be thoroughly understood. As they have already proven very practical, any person with mechanical ideas and a little ingenuity can see many more uses to which they can be put than those mentioned here.



MOTOR-DRIVEN AMERICAN ENGINE LATHE.

MAKING A MACHINIST

The boy, to be successful, must be willing to work and study. He must have ambition and common sense. He should realize that there is a great deal for him to learn before he becomes a machinist. He should have at least a common-school education. He has a good education if he has been taught how to learn and how to think intelligently.

He must be mechanical. If not, he can become a machine hand; that is, he may, after a time, become able to run a machine; but he will never make a machinist in the highest sense of the word. He should be on time at his work. The clock will go faster if he does not watch it, and he will do more and better work. He should study mechanical drawing. He should take a course in a good correspondence school.

He should get together a good kit of machinist's tools as fast as he can afford it; for he will find later that it makes a very poor impression on his shopmates and foreman if he has to borrow tools for the first job given him in a new shop. Cigarette money can be used to buy tools and help the boy. Cigarettes help the tobacco trust and the undertaker. I am convinced that the boy who has formed the habit of smoking cigarettes cannot become a good machinist. I have never seen a boy of this class who was not stupid; and I have not been able to decide whether they smoked cigarettes because they were stupid or were stupid because they smoked cigarettes; but I do know that the boy who habitually smokes them is stupid, dull, listless, dazed, and useless in a machine shop.

The boy should not be discouraged if his foreman does not at once notice that he is the brightest boy that ever came into a shop. He should give the foreman a little time. It will be noticed, if this is so, and that without having to be told about it. He should remember that he has been blessed with two eyes and two ears and but one tongue. This is not a mistake of nature.

He should try how well he can do the work given him, not how much he can do, until he becomes familiar with it. He will find that speed will come with practice. Above all, he must be thorough, and he should think of his work. He should remember that the men in the shop know what he does not know. He will lose nothing by admitting the fact. He should be obliging. If he shows a disposition to take hold and help when needed, he will find that the man helped will help him; and the boy needs it more than the man.

He should take at least one good trade paper. A good trade paper is up to date. The new work—the work that men are doing to-day—is being discussed therein, and he will be greatly benefited thereby. Mechanical books are good; but the trade paper is better, because the machinist's business is changing so rapidly—new tools are being brought out and old ones improved to such an extent—that he can keep in the procession only by keeping thoroughly posted. In doing this, the trade paper will be of great assistance. He should read the advertising pages. He should make a collection of manufacturers' catalogues, many of which to-day are good books of reference.

The boy should apply in person for a position. A dear old lady once called upon me to get a position for her boy. After her description I was surprised when he showed up. He said his name was "Willie." He was nearly six feet long and a few inches wide. He was a dear, good boy; but he could not stand the good-natured chaff of the other boys in the shop, and went back to his mother. He was a veritable, irritable mother's boy.

The boy will not be given good work at first. The way to get good work is to do well what is given him. The foreman can judge of his ability only by the manner in which the work given him is done; and he may be certain that he will not be trusted on better work until he has shown that he is worthy of the confidence. The new apprentice, in many shops, has to keep the floor clean. He should remember that oily waste and sweepings are more liable to catch fire when at the bottom of a barrel than on the floor, no matter what is on top to hide them. He should keep the floor clean under the benches. I am always willing to risk the middle of the floor if the boy will clean the corners. The oil that goes on the floor is wasted. It is not necessary to give every part of the machine a bath, although it may be so dry that it is screeching for a drink. Oil should go on the bearing surfaces, and it will not go there if the oil holes are plugged with dirt.

If running a lathe, he should not keep the feed just fast enough and coarse enough to escape the criticism of his foreman. A machine tool should not be abused; but it should be run to its fullest capacity. In roughing out work, care should be taken to leave stock enough to finish, but not enough to make more cuts than are absolutely necessary. Work held in a lathe-chuck should be supported if it stands out far enough to prevent taking a good chip without danger of breaking the tool. It will save time to get the steady rest on it.

In running a planer, the tool must have time to drop back into position for cutting. On fine work, enough space should be allowed for the planer platen to start back smoothly before the tool touches the work; but the platen should have rush orders to get back and do something. The boy is not earning money while the planer tool is cutting air. He must think, on planer work, not how many straps can be used, but how few; but enough must be used to hold the work, and they must be so arranged that the work is not sprung out of shape. The tools must be kept sharp and in good condition.

A hole cannot be tapped out the size ordered if drilled the full size of the tap. A one-inch drill will not drill a one-inch hole if the point of the drill is ground a sixteenth of an inch off the center. The operator should not drill full size into the work before finding out whether or not the drill is cutting where he wants the hole. A twist drill may make the hole just where it is wanted without running off on one side; but if the operator is not drilling through a bushed fixture, he had better find out. He can change it, and make a good piece of work, only if it is done before the drill cuts full size. This mistake is made every day, and it is one piece of carelessness for which there is no excuse. It is the operator's business to know, not to guess, that it is all right; and the fact that it was center-punched and laid out all right does not prevent the drill from running. A tap will not go any further after it has struck the bottom of the hole. We have all proved it. The boy should not try it. He may have more pieces when he gets through, but he will wish he had but one before he gets the broken pieces out. The boy can not ream a hole one inch if he has drilled it an inch and a thirty-second, and he can and will do this with a drill the right size for the reamer, if he is not attending strictly to business.

The boy should not make excuses. It does him no good to tell his foreman that he "did not think of that." He is paid to think of what he is doing, and he will never amount to anything if he does not think. The machinist who has graduated from a large, well-equipped shop is in many cases at a disadvantage when compared with the man who has learned his trade in a large job shop; because the job-shop machinist seldom has everything to work with and must devise means and fixtures for nearly every piece of work given him. He learns to think, and to think quickly and intelligently. He cannot go to the tool-room or stock-room and get tools or material for every job, and he must depend largely upon his own resources. There is no time, on most repair work, to get out drawings or patterns, fixtures or tools. The work must be done, and done at once. The customer is there waiting for it; and often the whole shop knows it, as his factory may be shut down at a great loss.

In the small shop or job shop, the man must be capable of doing his own thinking; and the boy starting in a job shop is generally put helping the older hands, and has a better chance to see and learn how the work is done. In the large shop, a great deal of the planning and thinking is done for him; he is supplied with all the special tools, fixtures and drawings, so that if he is a good machine operator he can do good work; but he can not do it alone. He is part of a machine, and is at a loss when anything new or irregular comes up. In a large, up-to-date shop, he learns the use of modern tools, and sees more of the new methods and fixtures for turning out good work quickly and cheaply; but he does not get the variety of work he would in the smaller shop, and is therefore more apt to beome a specialist on some particular machine—that is, more of a machine operator than a machinist in the largest sense—because economy in production comes from keeping a man on the same work so that he becomes expert in that line. Therefore, in the large shops, we are more apt to find lathe hands, planer hands, milling-machine and drill-press hands, and so on, than the regular all-round machinist. Of course it is much easier to become expert on one machine; but the young man we have in mind is ambitious, and does not intend to be always holding down a job for day's wages. He wants a position with a salary attachment, and therefore he should endeavor to obtain a working knowledge of every part of the machinist's trade. He cannot afford to overlook any part of it. He should know how to do the work himself to be able to direct others later; and he will find that moulding, pattern-making, sheet-iron work, blacksmithing, and a number of other trades are so closely allied with the machinist's trade that he should take advantage of every opportunity to become familiar with all the mechanical trades. He will need it all later; and, once obtained, it is easily carried from place to place, with nothing to pay for excess baggage. He should study steam and its properties, thus becoming familiar with the steam engine and its wonderful simplicity and efficiency; gas and the gas engine and its wonderful eccentricities; electricity and its vivid unexpectedness. In fact, the avenues of knowledge which open up and radiate from a study of the machinist's trade, impress upon us the comparitively small amount of knowledge it is possible to acquire in a lifetime.

The boy will never have learned it all in the machinist's trade. It will take him years, perhaps, to find out how little he knows; but after he does learn this, if he is the right kind of boy, his progress will be rapid. The machinist's trade is hard work in some respects, but extremely interesting. He will get his hands soiled, but the money is clean and honestly earned.

The man who claims that he is doing all he is getting paid for and will work hard to do no more, is generally paid for more than he does, and is at a standstill as far as promotion is concerned. He is liable to be out of work a good part of his time, and abuse of the foreman who discharged him does not help him to get another position. It is the cheap man who is always looking for work — the man who cannot stand alone, and who must have some one else to do his thinking for him. To the boy who is just starting at the foot, the top of the ladder may seem a dizzy height; but if he will work and think, giving his whole mind to what he is doing, he will soon find that the rungs are not far apart and that many of them are already below him. Also, that each step accomplished makes the next one easier. The world owes him a living; but this is not an asset unless he hustles. He should not be too anxious about the amount of his salary at first. All through life he will get less than he thinks he is worth. He may be worth less than he thinks, although not worthless by any means. A man has to earn more than he receives before he can get more; the greater he makes this difference, the greater will be the increase when it comes, and the more apt it is to come. He should get into the habit of proving all that he does; and this habit should enable him, not only to know when he is worth a larger salary, but to prove it to his employer.

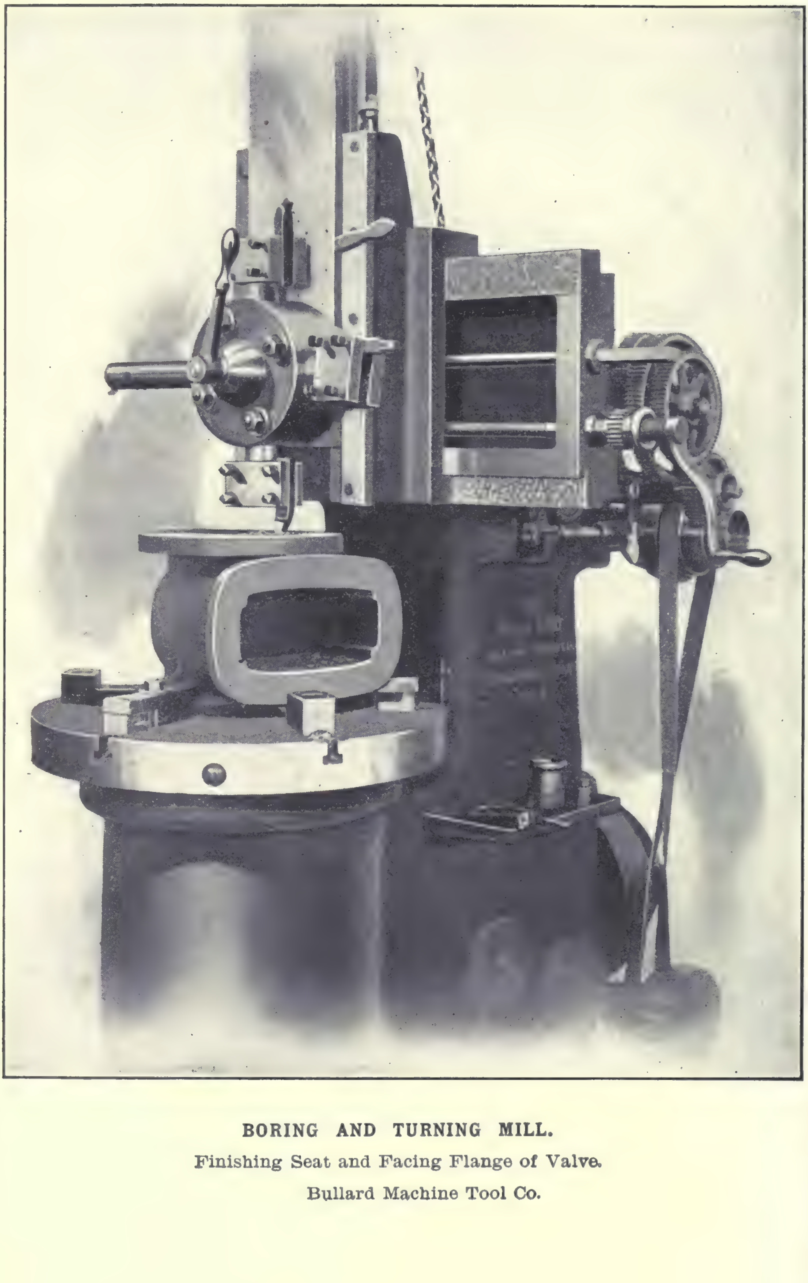
The good machinist is seldom out of employment; and while the average rate of wages is less than in some other trades, he has steady work and is inside, so that he does not lose time and wages on account of the weather. An engineer is worth more if he is a machinist and can do his own repairs, or, in larger plants, oversee them and know that the work is done correctly. A thoroughly good machinist has learned to take nothing for granted, and knows that "eternal vigilance is the price of good work." For this and many other reasons, his training fits him for positions of responsibility; and the chances of successful careers for bright, capable boys are better to-day than ever before in the machinist business. One of the hardest things in life is the fact that a man has to have years of experience before he is willing to admit, even to himself, the magnitude of his ignorance. It is only the very young who know it all. The young man of twenty is willing and anxious to give advice; the man of forty is willing to pay to get it, but he seeks it from men of experience.

In the line of invention, the opportunities are greater than in any other business. The machinist may obtain patents for his inventions, which, when assigned to his employer, may be worth thousands of dollars to the latter, and this often without losing his position; while he has the satisfaction of knowing that his inventions have advanced the interests of his employer if not his own. And you know we are taught that it is not right for the employee to be too selfish. The inventor has probably done more for the world and less for himself than any other individual. And this is none the less true because, when the patent is allowed, he usually wants an even million dollars for it. Many inventors still want it.

The world owes more to the machinist than is generally realized. The splendid position of the United States in the world to-day is largely due to her machinists, who, by their special tools and labor-saving machinery, designed and built by machinists, have made it possible for her to compete successfully with foreign manufacturers, and have enabled her to sell and to deliver to all parts of the world, freight paid, manufactured products at a less price than the cost of manufacture would be in those places, and this at a fair profit. The unfair profit is obtained by charging her own citizens a higher price, and allowing them to pay the freight. The fact that we can build better bridges, build them cheaper, and deliver them on time—and the time about half what other countries require—is largely due to our labor-saving machinery. The *Oregon*, the rapid-fire gun, the bicycle, the horseless carriage, the steel sky-scraper, the Brooklyn bridge, the locomotive, the sewing-machine, have all been made possible and practicable by the machinist. In fact, it would be next to impossible to mention anything manufactured that does not depend more or less for its excellence upon the machinist. He manufactured the article in question, or he made the machine that manufactured it; and he designed and made the tools that made the machine possible.

There is, perhaps, no other trade, and very few professions, that require the high order of intelligence, the study, the application, the real hard-headed common-sense, the surgeon's delicacy of touch—for instance, in the fitting of fine work—that the machinist's trade demands to give the excellent work and the interchangeability of parts found in the modern rifle or sewing-machine. The range of his work is from a needle to a battleship; from automatic machinery that "would talk French if it had one more movement" to measuring machines guaranteed not to vary more than the fifty-thousandth part of an inch from the absolute. This precision will perhaps be better appreciated when it is remembered that one hundred and fifty times this limit of variation is only equal to the diameter of the average human hair Standard plug and ring gauges, to take a specific example, are so accurately fitted to each other that the expansion due to the warmth of the hand, if the plug be held in it for a few moments, will make it impossible to insert the plug in the ring; while if the ring be expanded in the same way, the plug will drop clear through it.

When the machinist has become skillful enough to fulfill the above requirements, he may receive from $2.50 per day up to whatever he can make himself worth and prove it. The wonderful activity in manufacturing at the present time will increase owing to the growth of the United States; or the growth of the United States will increase owing to the wonderful manufacturing activity. Whichever way you look at it, machinists will be in demand; and, although we have so many first-class men, the demand for really good men is greater than the supply.



BORING AND TURNING MILL.

Finishing Seat and Facing Flange of Valve.

Bullard Machine Tool Co.

THE IDEAL FOREMAN.

Qualifications Requisite for His Highest Success.

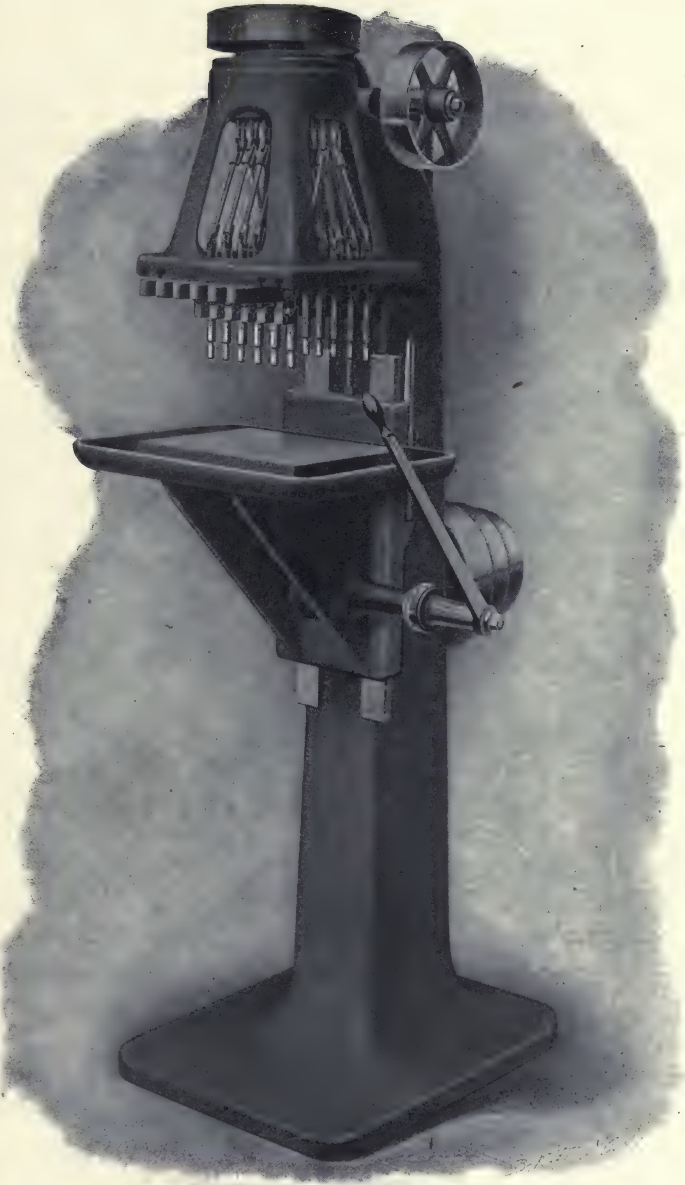
Any attempt to outline an ideal is apt to be met with many differences of opinion, if not actual denials. One reason for this difference of opinion is found in the fact that ideals are always on a sliding scale The ideal of to-day becomes the realization of to-morrow, and the point of view depends upon how far up the ladder of idealism the observer has advanced. To borrow an illustration from the shop, probably every workman remembers that on entering the factory as an apprentice, his boyish ambitions were centered on advancing to a position occupied by some workman well up the line, who, in the opinion of the apprentice, was better dressed and had an easier task than his fellows. In the course of time, if the young man was ambitious and persevering, he probably occupied this or a similar position, and then found, to his dismay, that his ideal had changed, and that he now looked forward to occupying the position held by the foreman or superintendent. In other words, viewed from the point of attainment, an ideal is a will-o'-the-wisp, always keeping just beyond our reach. It is well that this is so, for there is no human failure so complete as the man who is entirely satisfied with himself.

From another point of view the ideal is a movable feast, because, to quote an example from our subject, the ideal foreman of the apprentice is not that of the skilled mechanic, while the views of the owner on this subject are almost sure to be at variance with those of any of the workmen. We can readily appreciate how the bright boy idealizes the man who treats him kindly and who gives him an opportunity to learn. The lazy boy feels kindly disposed toward the foreman who gives him an easy task. The poor and careless workman wants a foreman who will pass work which is not a credit to the craft, and who is blind to the evils of laziness and, possibly, to those of the drink habit. The skilled workman asks nothing of a foreman but to be treated like a man, to be given a proper share of the desirable work, and to be allowed to work out his own salvation along these lines. The owner looks to his foreman to make money for him. In many cases, he expects him to make more money than the capital invested and the methods pursued will warrant. This means that the foreman is expected to crowd the workmen to the limit, and to keep both the plant and the help as near the breaking point as it is possible to carry them. Some owners and managers, however, are content with a reasonable return on their property, pursue up-to-date methods, and give to the workmen some thought beyond their mere capacity to earn dividends. It is to be regretted that men of this type are not more often found in positions where their humane policy can be held up as an example to those of a more sordid and grasping nature.

It having been shown impossible to outline an ideal foreman, when viewed from these different standpoints, evidently the discussion of what a foreman should be can be no more than a statement of the personal opinion of the writer.

Before all other qualifications, it is necessary that the foreman should be what the word implies—first, a man; and, second, a leader. If he is a man in the true sense of the word, he cannot fail to be respected by all self-respecting workmen. If he is an honest leader, he will conduct those workmen along the lines laid down by the owners as the policy of the establishment. Too often the foreman is looked upon merely as the buffer between the firm and the men. He is supposed to act as peacemaker, and to keep them from flying at one another's throats. Under such conditions, it is obviously impossible that a man can be in full favor with either party. Toward the firm the foreman should be respectful, obedient, and energetic; toward the workmen he should be firm, just, and sympathetic.

Of all the qualities going to make the ideal foreman, that of tact is the most important. It means that the men will be treated as individuals, their failings noted and corrected, their good points enlarged upon and due credit allowed for them, and that the shop life will be freer and more natural. With this tact, or faculty of governing along the line of least resistance, must be coupled absolute fairness. Nothing will create such an atmosphere of discontent as a suspicion that the foreman has favorites. If these supposed favorites happen to be relatives of the foreman, the idea is much harder to combat. For that reason, personal friendship



MULTIPLE SPINDLE DRILL.
Pratt and Whitney Co.

and family obligations will be left outside the shop by the man who wishes to succeed as a leader of workmen. A decided, but not aggressive, manner of passing upon questions serves to inspire the men with respect for the foreman, especially if such decisions are rendered promptly, and they prove in the large majority of cases, to be accurate. Having made a decision, or taken a decided stand on any matter, it will not do to deviate from that position, unless it is so clearly wrong as to be apparent to the casual observer.

Fairness, dignity, and firmness are qualities that can be quite closely defined; but tact and its fellow attribute, executive ability, are rather elusive of close description. They are of the inherited type and can be cultivated only to a very limited extent. If a man does not possess tact and executive ability, it is useless for him to accept a position where they are essential, in the belief that they will develop as required.

While workmen are supposed to be paid only for the time spent in the shop, it is also true that a man's value cannot be reckoned entirely by the quality of his work and the number of hours of labor. His conduct outside the factory invariably leaves its impress on his conduct within and on the product of his work. This is even more noticeable in the case of a foreman, for, although workmen generally would deny it, they do not and cannot have a wholesome respect for a foreman who is not respected by the community. Men will say they do not care what a foreman is outside the shop; but their better nature will not allow them to look up in any sense to a social pariah.

While an absolute grasp of all the details of the business, viewed from the workman's standpoint, is not absolutely necessary to a foreman possessing tact and executive ability, it adds greatly to a foreman's prestige to be able literally to show any workman just how any operation should be performed.

Just a word in illustration of tact in dealing with men of radically different temperaments. The blustering workman, so familiar to all foremen, can be best controlled by a very quiet and soft-spoken superior, especially if the foreman in question has the reputation of firmness and fair dealing. The quiet, positive statement, coupled with a refusal to discuss the matter, is so contrary to the blatant workman's usual procedure, that it takes away his only weapon by not allowing him to use it. On the other hand, it often happens that the quiet man of few words can be spurred on to better deeds by an energetic and insistent manner on the part of the foreman. Of course, this all goes to prove the foreman's tact, and to disprove the oft-repeated statement that workmen should all be treated alike. The best results cannot be obtained in this manner. Until men are all turned out in the same mould, it will be necessary to suit the treatment to the temperament of the man.

The question of how far it is advisable to show sympathetic nature, is one of grave doubt. Sympathy does not mean that excuses are to be taken literally; but a casual inquiry as to how the sick wife or baby is getting along shows an interest outside the commercial relation that appeals to most men. The old saw, "You catch more flies with molasses than you do with vinegar", has an application in the treatment of workmen by their foreman.

Another question which has more than one answer, is whether it is better to have a foreman promoted from the ranks or to get an outside man for the position. The man from the bench is familiar with all the shop traditions and practices, and can keep things going with hardly a break. On the other hand, he is the victim of jealousy and spite, and, unless exceptionally well-poised, is apt to assume an attitude toward his former shopmates which might be termed "dignity gone to seed". Every youthful indiscretion is remembered, and any attempt to check such antics on the part of the younger men is held to be an unwarranted assumption of dignity. On the whole, the attempt to promote a foreman from the floor or bench is fraught with difficulties; and many a man who would have made an excellent foreman in another shop, has been a rank failure in that capacity when tried among his old shop associates. The foreman taken from the outside stands or falls, as far as the workmen are concerned, on his record in his new position. He is not condemned for past faults. Furthermore, he should be able to bring into his new associations some of his experience in former situations which will be of value to his new employers. It is an infusion of new blood and is often the means of discovering leaks and weaknesses not noticeable to the old employees.

A foreman's value to a firm depends largely on his knowledge of the capacity and limitations of each man under him. This knowledge enables him to lay out his work to the best advantage, as he knows the man who is quick, the man who is accurate, and the man who can be trusted to carry along detail or experimental work. To keep a man up to his best pace, to have new work laid out for him in advance, and to keep that man satisfied with his work and wages, is a task that taxes the ingenuity of the best of foremen. The matter of repairs, especially those of a petty nature, is one which tests a foreman's commercial sense more than the regular run of work does. As an example, suppose that the friction on a countershaft slips; shall the oiler be sent for while the machine operator waits; shall the workman fix it himself; or shall the man be transferred to another machine while the repair work is going on? Of course, this all depends on the nature and degree of the difficulty; but it affords an opportunity for quick and accurate judgment on the part of the foreman, and demonstrates his fitness to cope with emergencies.

An article of this character should not be closed without a reference to that old-time figure, the "working foreman". Do not all machinists of mature age remember how the foreman would walk down the shop with a piece of work and a file in his hand, filing as he went? Even in these days of strenuous competition, we sometimes see an advertisement for a "working foreman". It is preposterous to think that a foreman can properly supervise the operations of more than a dozen men, and do any work that calls for close attention. Many firms insist on this practice, however, and are daily losing money by its continuance. A foreman should be devoting his energies to the development of better methods of manufacture, and not to the production of work that could be performed by one of the machinists.

And so we leave the ideal foreman, not yet discovered, not even closely defined, but anxiously awaited and badly needed.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for Civil Service Examinations. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

PART I

1. Give the meaning of approximate and precise measurements. Give examples and reasons for employing either method when doing the individual piece of work.

2. When making single-lip drills why is it necessary to remove exactly one-half the diameter as shown in Fig. 19 ?

3. When making the taper reamer, called a stepped reamer (Fig. 51) why are the steps made straight rather than tapering ?

4. When a mandrel is held in V blocks when laying off the center line as shown in Fig. 67, how would you find the exact location by precise measurements ?

5. Why is it advisable to cut the threads of an adjustable tap somewhat smaller than the desired size for the tap to cut ?

6. What would be the effect if a piece of work were turned to finish dimensions, when the live center of the lathe did not run true ? If the dead center is not to gauge ?

7. Why will a twist drill cut faster and make a truer hole than a flat drill ?

8. State in your own language the result attained by using a reamer holder of the design shown in Fig. 58.

9. When extreme accuracy is required, why is not advisable to grind the essential part of a milling machine arbor before it has the spline cut ?

10. Why is it desirable for a tap to retain its correct pitch when hardened ? What would be the effect were it to elongate? What if it should contract ?

11. How should a piece of round tool steel be centered for turning in the lathe?

12. Explain the method used to prevent a fluted reamer from chattering. What should be taken into consideration in designing the tooth?

13. When making mandrels why should the center holes in the ends be deeper than in the case of most tools?

14. When is it allowable to cut the threads of a tap by means of a screw-threading die?

15. State in your own language the objection to reaming holes that must run perfectly true, and why it is considered allowable to ream a hole that is to be approximately true as, for instance, the hole for receiving the tap in the tap holder shown in Fig. 105.

16. When is it advisable to use a high-carbon tool steel? When a low? Give example.

17. When cutting the grooves in a reamer having 8 cutting edges, state the number of holes the index pin should be moved each time in order to get an uneven spacing that will diverge by 2° to 4° from an angle corresponding to equal spacing. Assume that the dividing head on the milling machine requires 40 turns of the index pin for one revolution of the spindle. Assume the pin to be set in the circle having 20 holes.

18. What would be the result if the centers were not given the extra countersink, or recess cut as shown in Figs. 60 and 61?

19. Why should the lands of a hand tap be wider than those of a machine tap?

20. Why is it necessary to use a releasing tap holder when tapping holes where the threads go to, or nearly to the bottom of the hole?

21. What is the effect of uneven heating of tool steel for hardening? Why?

22. Why is it advisable to use a form of grinder having two dead centers when a piece of work is required exactly round?

23. Why should the center of a mandrel be lapped to an angle of 60 degrees before the mandrel is ground to size?

24. What would be the result were the threads of a taper tap cut with a tail block set over to give the required taper?

25. Suppose a screw die hob were made with the same num-

ber of flutes and of the same proportions as hand taps. What would be the results if it were run into a screw-thread die which had been provided with clearance holes ?

26. When are flat drills used ? Why ?

27. When making the adjustable reamer shown in Fig. 47 what would be the result when it was hardened if the slots were cut to the end of reamer ?

28. When making the sleeve for the expanding mandrel shown in Fig. 65, why should it not be held in a grinder chuck when grinding the hole to size ?

29. Why should steel for a cutting tool be chosen somewhat larger than finished size ?

30. Why is it necessary to reheat large pieces after they have been hardened ?

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

PART II

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1. Why is it not advisable to make the lands of screw threading dies wider than described? What is the result if they are made narrower?

2. Under what circumstances would you consider it advisable to use a counterbore, rather than a drill when enlarging a hole. Why?

3. Why would it not be considered good practice to turn the piece of stock represented in Fig 131 to size before drilling the holes and working the slots to size?

4. Why is it not advisable to make a hollow mill to be used in roughing out work, having more than 4 teeth?

5. Why is it advisable to give a finish hollow mill more than 4 teeth?

6. When hardening a hollow mill of the form shown in Fig. 147, why is it advisable to dip it in the bath with the cutting edges uppermost?

7. In using a forming tool why is it necessary to have the face of the tool at the height of the center?

8. Give the advantages derived from using a forming tool and holder of the design shown in Fig. 162.

9. Why is a milling-machine cutter more likely to crack when hardening than other forms of tools?

10. Why is it not good practice to ream holes in milling-machine cutters to finish size?

11. What is the result if the hole in a milling-machine cutter does not fit the arbor?

12. When is it advisable to use milling-machine cutters having interlocking teeth ?

13. When is it advisable to use milling-machine cutters having their teeth cut spirally ? Why ?

14. When is it advisable to cut the teeth of milling-machine cutters with a right-hand spiral ? When a left-hand spiral ? Why ?

15. State advantage gained in making milling-machine cutters with nicked teeth.

16. Why is it generally considered advisable to make milling-machine cutters that are larger than 6 or 8 inches diameter with inserted teeth.

17. When a blank for a milling-machine cutter that is to have inserted teeth is milled with slots that are at angle to the cutter axis, why is it not advisable to leave the faces of the teeth at that angle ?

18. If an emery wheel, 3 inches in diameter, is used in grinding the teeth of a milling-machine cutter, how many revolutions must it make in a minute in order to run at a peripheral speed of 5,000 feet per minute ?

19. Why is it not generally considered good practice to make key ways in milling-machine cutters with sharp corners ?

20. State in your own language the generally accepted meaning of the term "formed cutter" or form cutter.

21. Name some of the advantages derived from the use of formed cutters.

22. What would be the result if the faces of the teeth of a formed mill were not recut after they were backed off ?

23. When backing off the teeth of a formed mill, what would be the result of setting the forming tool above or below the center of the work ?

24. When making milling-machine cutters with threaded holes, why is it necessary to first thread the blank, then machine it on a threaded mandrel ?

What would be the result were the cutter machined to shape before threading the hole ?

25. When machining a piece of work having a threaded hole, why is it not advisable to screw the piece onto a threaded mandrel in such a manner that the shoulder of work is against the shoulder of mandrel when squaring the first end ?

REVIEW QUESTIONS

ON THE SUBJECT OF

TOOL MAKING.

PART III

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1. Why should undue accuracy never be indulged in when making drill jigs and similar tools?

Give examples where *extreme* accuracy is not desirable.

Give examples where it should be observed.

2. When making bushing holes in drill jigs by the method illustrated in Fig. 228 *why* are more satisfactory results obtained if the cutting end of counter bore is made of the form shown in Fig. 229.

3. State in your own words the reason for obtaining location of bushing holes in drill jigs by means of locating buttons and lathe indicator.

4. Why are drill jigs for permanent equipment provided with hardened steel bushings?

5. Name the different forms of drill bushings commonly used in jigs.

Name the good features of each.

Name the objectional features of each.

6. What is the objection to using the ordinary shop mandrel for holding bushings when grinding to finish size?

7. When drilling the block illustrated in Fig. 251 why is it advisable to first use the transfer drill shown in Fig. 254?

8. When reaming the holes in block shown in Fig. 251 why is it advisable to use the piloted single lip reamer? (Fig. 253)

9. Explain the office of the guide and stop used on a punching press blanking die.

10. Why are blanking dies for press work given clearance?

Where are they given a small amount?

Where are they given excessive clearance?

11. When milling the opening of blanking die for use on punching press work, if no milling cutter of the proper taper were available, and you were obliged to use a straight cutter, how would you get the desired clearance?

12. Why are the faces of punching press blanking dies made shearing?

When is it allowable? When not?

13. When hardening a blanking die for punching press work why is it necessary to heat the die *uniformly throughout*?

14. Why are blanking dies sometimes made in the form of sectional dies?

15. When are punches made to *fit* the opening in a blanking die?

When are they made smaller?

16. When making a die for use in punching a piece of irregular outline whose opposite sides are not alike as shown in Fig. 277, why is it necessary to observe care when marking the face of the punch from the templet used in laying out the shape of the aperture in the die?

17. Explain the process of shearing a punch into a die.

18. When is it necessary to place the stripper on the punch rather than on the die? Why?

19. When making a gang die of the form shown in Fig. 283 explain the method of locating the stop pin?

Why is it so located?

20. When using the gang die shown in Fig. 283 what would result were the punches B′, and B longer than the punch A

21. When making bending dies of the description shown in Fig. 289 name the various points necessary to take into consideration.

22. When is it necessary to use gauges?

23. Under what circumstances is it advisable to finish contact surfaces of gauges by lapping?

Why is it necessary?

24. Why should the ends of plug gauges be left as shown in Fig. 296 or Fig. 297 until the gauge is lapped to size?

25. When *finish* lapping a ring gauge to size why is it necessary to grind the lap perfectly round?

26. When are snap gauges used?

Why are they used in preference to a micrometer on ordinary work?

27. When making a snap gauge of the description shown in Fig. 306 why is it necessary to leave a small amount of stock on each contact surface until after the gauge is hardened?

28. When grinding the contact surfaces of snap gauges, what points must be observed?

29. Give an example other than the one illustrated, where the use of a limit gauge would be advisable.

30. When making receiving gauges what points must be observed? Why?

31. When making the locating gauge shown in Fig. 327, why is it allowable to locate the first pin by *approximate* measurements and not the other?

REVIEW QUESTIONS

ON THE SUBJECT OF

METALLURGY.

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1. What is blister steel? How is it made?

2. What takes place when cast iron is made into wrought iron? Name the principal process.

3. Name three ores of iron with their approximate percentages of iron.

4. Why is the percentage of silicon important in iron castings?

5. What are the advantages of the Bessemer process of making steel? Of the Open Hearth process?

6. Explain the process for reducing iron ore to metallic iron. Give reaction.

7. What is the advantage of heating the blast of the blast furnace?

8. By what method is wrought iron made directly from the ore?

9. Give some of the qualities of pig iron. What chemical elements does it usually contain?

10. Why has mild steel replaced wrought iron? Why is wrought iron more easily welded than mild steel?

11. What is flux? What is slag?

12. Why does pig iron make good castings?

13. What is spiegel? State its use and approximate composition.

14. Describe briefly the Bessemer converter.

15. Of what is the lining made in the "acid" Bessemer converter?

16. Describe briefly the process of tempering. What color denotes the hardest temper?

17. What is the influence of manganese on pig iron? On steel?

18. Why is steel made in the crucible superior to both Bessemer and Open Hearth steels?

19 How is the melter able to judge when the Bessemer converter charge is ready to pour?

20. State some of the qualities of nickel steel. How is it "face hardened" in making armor plate?

21. What fuel is used in the Open Hearth process? Why?

22. What are Siemens regenerative chambers?

23. How is carbon expelled in the Open Hearth process? Write and explain the chemical reaction.

24. Describe briefly the blast furnace.

25. What is self hardening steel?

26. What fuel is used in the blast furnace?

27. What is the most important ore of lead? Of copper? Of tin? Of zinc?

28. What is a copper matte?

29. A piece of boiler plate (mild steel) is $\frac{7}{8}$ inch thick, 2 feet wide and 3 feet long. How much does it weigh?

30. Find the weight of zinc in 48 cubic inches of brass.

31. What is the principal use of copper? Of tin? Of zinc?

32. What is the shape of a lead blast furnace?

33. How is zinc produced?

34. How is galvanized iron made?

35. What are alloys? What is the composition of Muntz metal?

36. How is aluminum obtained? How does its electrical conductivity compare with that of copper?

37. What is the advantage of the electrolytic process of refining crude copper?

38. On what properties does the Park's process of desilverizing lead depend?

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